CARNEGIE INSTITUTION

OF

WASHINGTON

YEAR BOOK No. 18

1919

PUBLISHED BY THE INSTITUTION
WASHINGTON, U. S. A.
MARCH 1920

PRESS OF GIBSON BROTHERS, INC.
WASHINGTON, D. C.

OFFICERS FOR THE YEAR 1919.

*Ex officio member. †Died November 14, 1919.

LIST OF PRESENT AND FORMER TRUSTEES.

ASSOCIATES OF THE INSTITUTION.

DIRECTORS OF DEPARTMENTS OF RESEARCH.

LOUIS A. BAUER, Department of Terrestrial Magnetism.
FRANCIS G. BENEDICT, Nutrition Laboratory.
BENJAMIN BOSS, Department of Meridian Astrometry.
CHARLES B. DAVENPORT, Department of Experimental Evolution.
ARTHUR L. DAY. Geophysical Laboratory.
GEORGE E. HALE, Mount Wilson Observatory.
J. FRANKLIN JAMESON, Department of Historical Research.
DANIEL T. MACDOUGAL, Department of Botanical Research.
ALFRED G. MAYOR, Department of Marine Biology.
GEORGE L. STREETER, Department of Embryology.

INVESTIGATORS PRIMARILY CONNECTED WITH THE INSTITUTION.

WILLIAM CHURCHILL, Associate in Primitive Philology.
FREDERIC E. CLEMENTS, Associate in Ecology.
OLIVER P. HAY, Associate in Paleontology.
ELIAS A. LOWE, Associate in Paleography.
SYLVANUS G. MORLEY, Associate in American Archeology.
GEORGE SARTON, Associate in the History of Science.
ESTHER B. VAN DEMAN, Associate in Roman Archeology.
GEORGE R. WIELAND, Associate in Paleontology.

OTHER INVESTIGATORS.

CARL BARUS (Brown University), Research Associate in Physics.
HENRY BERGEN, Research Associate in Early English Literature.
V. BJERKNES (University of Bergen, Norway), Research Associate in Meteorology.
E. C. CASE (University of Michigan), Research Associate in Paleontology.
W. E. CASTLE (Harvard University), Research Associate in Biology.
T. C. CHAMBERLIN (University of Chicago), Research Associate in Geology.
HENRY E. CRAMPTON (Columbia University), Research Associate in Biology.
H. D. FISH (Denison University), Research Associate of Department of Experimental Evolution.
DIXON R. FOX (Columbia University), Research Associate in History.
J. C. W. FRAZER (Johns Hopkins University), Research Associate in Chemistry.
JOHN F. HAYFORD (Northwestern University), Research Associate in Physics.
HENRY M. HOWE (Columbia University), Research Associate in Metallurgy.
J. C. KAPTEYN (University of Groningen), Research Associate of the Mount Wilson Observatory.
C. C. LITTLE (Harvard University), Research Associate of Department of Experimental Evolution.
ALBERT MANN, Research Associate in Biology.
L. B. MENDEL (Yale University), Research Associate in Physiological Chemistry.
A. A. MICHELSON (University of Chicago), Research Associate of the Mount Wilson Observatory.
T. H. MORGAN (Columbia University), Research Associate in Biology.
FRANK MORLEY (Johns Hopkins University), Research Associate in Mathematics.
H. N. MORSE (Johns Hopkins University), Research Associate in Chemistry.
F. R. MOULTON (University of Chicago), Research Associate in Mathematical Physics.
E. L. NICHOLS (Cornell University), Research Associate in Physics.
A. A. NOYES (Throop College of Technology), Research Associate in Chemistry.
THOMAS B. OSBORNE (Connecticut Agricultural Experiment Station), Research Associate in Physiological Chemistry.
T. W. RICHARDS (Harvard University), Research Associate in Chemistry.
H. C. SHERMAN (Columbia University), Research Associate in Chemistry.
EDGAR F. SMITH (University of Pennsylvania), Research Associate in Chemistry.
JOHN S. P. TATLOCK (Leland Stanford Junior University), Research Associate in Literature.

CONTENTS.

ORGANIZATION, PLAN AND SCOPE.

The Carnegie Institution of Washington was founded by Mr. Andrew Carnegie, January 28, 1902, when he gave to a board of trustees an endowment of registered bonds of the par value of ten million dollars. To this fund an addition of two million dollars was made by Mr. Carnegie on December 10, 1907, and a further addition of ten million dollars was made by him January 19, 1911; so that the present endowment of the Institution has a par value of twenty-two million dollars. The Institution was originally organized under the laws of the District of Columbia and incorporated as the *Carnegie Institution*, articles of incorporation having been executed on January 4, 1902. The Institution was reincorporated, however, by an act of the Congress of the United States, approved April 28, 1904, under the title of *The Carnegie Institution of Washington.* (See existing Articles of Incorporation on the following pages.)

Organization under the new Articles of Incorporation was effected May 18, 1904, and the Institution was placed under the control of a board of twenty-four trustees, all of whom had been members of the original corporation. The trustees meet annually in December to consider the affairs of the Institution in general, the progress of work already undertaken, the initiation of new projects, and to make the necessary appropriations for the ensuing year. During the intervals between the meetings of the Trustees the affairs of the Institution are conducted by an Executive Committee chosen by and from the Board of Trustees and acting through the President of the Institution as chief executive officer.

The Articles of Incorporation of the Institution declare in general "that the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind." Three principal agencies to forward these objects have been developed. The first of these involves the establishment of departments of research within the Institution itself, to attack larger problems requiring the collaboration of several investigators, special equipment, and continuous effort. The second provides means whereby individuals may undertake and carry to completion investigations not less important but requiring less collaboration and less special equipment. The third agency, namely, a division devoted to editing and to printing books, aims to provide adequate publication of the results of research coming from the first two agencies and to a limited extent also for worthy works not likely to be published under other auspices.

ARTICLES OF INCORPORATION.

PUBLIC No. 260.—An Act To incorporate the Carnegie Institution of Washington.

Be in enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the persons following, being persons who are now trustees of the Carnegie Institution, namely, Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, their associates and successors, duly chosen, are hereby incorporated and declared to be a body corporate by the name of the Carnegie Institution of Washington and by that name shall be known and have perpetual succession, with the powers, limitations, and restrictions herein contained.

SEC. 2. That the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind; and in particular—

(a) To conduct, endow, and assist investigation in any department of science, literature, or art, and to this end to cooperate with governments, universities, colleges, technical schools, learned societies, and individuals.

(b) To appoint committees of experts to direct special lines of research.

(c) To publish and distribute documents.

(d) To conduct lectures, hold meetings and acquire and maintain a library.

(e) To purchase such property, real or personal, and construct such building or buildings as may be necessary to carry on the work of the corporation.

(f) In general, to do and perform all things necessary to promote the objects of the institution, with full power, however, to the trustees hereinafter appointed and their successors from time to time to modify the conditions and regulations under which the work shall be carried on, so as to secure the application of the funds in the manner best adapted to the conditions of the time, provided that the objects of the corporation shall at all times be among the foregoing or kindred thereto.

SEC. 3. That the direction and management of the affairs of the corporation and the control and disposal of its property and funds shall be vested in a board of trustees, twenty-two in number, to be composed of the following individuals: Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D.

Wright, who shall constitute the first board of trustees. The board of trustees shall have power from time to time to increase its membership to not more than twenty-seven members. Vacancies occasioned by death, resignation, or otherwise shall be filled by the remaining trustees in such manner as the by-laws shall prescribe; and the persons so elected shall thereupon become trustees and also members of the said corporation. The principal place of business of the said corporation shall be the city of Washington, in the District of Columbia.

SEC. 4. That such board of trustees shall be entitled to take, hold and administer the securities, funds, and property so transferred by said Andrew Carnegie to the trustees of the Carnegie Institution and such other funds or property as may at any time be given, devised, or bequeathed to them, or to such corporation, for the purposes of the trust; and with full power from time to time to adopt a common seal, to appoint such officers, members of the board of trustees or otherwise, and such employees as may be deemed necessary in carrying on the business of the corporation, at such salaries or with such remuneration as they may deem proper; and with full power to adopt by-laws from time to time and such rules or regulations as may be necessary to secure the safe and convenient transaction of the business of the corporation; and with full power and discretion to deal with and expend the income of the corporation in such manner as in their judgment will best promote the objects herein set forth and in general to have and use all powers and authority necessary to promote such objects and carry out the purposes of the donor. The said trustees shall have further power from time to time to hold as investments the securities hereinabove referred to so transferred by Andrew Carnegie, and any property which has been or may be transferred to them or such corporation by Andrew Carnegie or by any other person, persons, or corporation, and to invest any sums or amounts from time to time in such securities and in such form and manner as are permitted to trustees or to charitable or literary corporations for investment, according to the laws of the States of New York, Pennsylvania, or Massachusetts, or in such securities as are authorized for investment by the said deed of trust so executed by Andrew Carnegie, or by any deed of gift or last will and testament to be hereafter made or executed.

SEC. 5. That the said corporation may take and hold any additional donations, grants, devises, or bequests which may be made in further support of the purposes of the said corporation, and may include in the expenses thereof the personal expenses which the trustees may incur in attending meetings or otherwise in carrying out the business of the trust, but the services of the trustees as such shall be gratuitous.

SEC. 6. That as soon as may be possible after the passage of this Act a meeting of the trustees hereinbefore named shall be called by Daniel C. Gilman, John S. Billings, Charles D. Walcott, S. Weir Mitchell, John Hay, Elihu Root, and Carroll D. Wright, or any four of them, at the city of Washington, in the District of Columbia, by notice served in person or by mail addressed to each trustee at his place of residence; and the said trustees, or a majority thereof, being assembled, shall organize and proceed to adopt by-laws, to elect officers and appoint committees, and generally to organize the said corporation; and said trustees herein named, on behalf of the corpora-

tion hereby incorporated, shall thereupon receive, take over, and enter into possession, custody, and management of all property, real or personal, of the corporation heretofore known as the Carnegie Institution, incorporated, as hereinbefore set forth under "An Act to establish a Code of Law for the District of Columbia, January fourth, nineteen hundred and two," and to all its rights, contracts, claims, and property of any kind or nature; and the several officers of such corporation, or any other person having charge of any of the securities, funds, real or personal, books or property thereof, shall, on demand, deliver the same to the said trustees appointed by this Act or to the persons appointed by them to receive the same; and the trustees of the existing corporation and the trustees herein named shall and may take such other steps as shall be necessary to carry out the purposes of this Act.

SEC. 7. That the rights of the creditors of the said existing corporation known as the Carnegie Institution shall not in any manner be impaired by the passage of this Act, or the transfer of the property hereinbefore mentioned, nor shall any liability or obligation for the payment of any sums due or to become due, or any claim or demand, in any manner or for any cause existing against the said existing corporation, be released or impaired; but such corporation hereby incorporated is declared to succeed to the obligations and liabilities and to be held liable to pay and discharge all of the debts, liabilities, and contracts of the said corporation so existing to the same effect as if such new corporation had itself incurred the obligation or liability to pay such debt or damages, and no such action or proceeding before any court or tribunal shall be deemed to have abated or been discontinued by reason of the passage of this Act.

SEC. 8. That Congress may from time to time alter, repeal, or modify this Act of incorporation, but no contract or individual right made or acquired shall thereby be divested or impaired.

SEC. 9. That this Act shall take effect immediately.

Approved, April 28, 1904.

BY-LAWS OF THE INSTITUTION.

Adopted December 13, 1904. Amended December 13, 1910, and December 13, 1912.

ARTICLE I.

THE TRUSTEES.

1. The Board of Trustees shall consist of twenty-four members, with power to increase its membership to not more than twenty-seven members The Trustees shall hold office continuously and not for a stated term.

2. In case any Trustee shall fail to attend three successive annual meetings of the Board he shall thereupon cease to be a Trustee.

3. No Trustee shall receive any compensation for his services as such.

4. All vacancies in the Board of Trustees shall be filled by the Trustees by ballot. Sixty days prior to an annual or a special meeting of the Board, the President shall notify the Trustees by mail of the vacancies to be filled and each Trustee may submit nominations for such vacancies. A list of the persons so nominated, with the names of the proposers, shall be mailed to the Trustees thirty days before the meeting, and no other nominations shall be received at the meeting except with the unanimous consent of the Trustees present. Vacancies shall be filled from the persons thus nominated, but no person shall be declared elected unless he receives the votes of two-thirds of the Trustees present.

ARTICLE II.

MEETINGS.

1. The annual meeting of the Board of Trustees shall be held in the City of Washington, in the District of Columbia, on the first Friday following the second Thursday of December in each year.

2. Special meetings of the Board may be called by the Executive Committee by notice served personally upon, or mailed to the usual address of, each Trustee twenty days prior to the meeting.

3. Special meetings shall, moreover, be called in the same manner by the Chairman upon the written request of seven members of the Board.

ARTICLE III.

OFFICERS OF THE BOARD.

1. The officers of the Board shall be a Chairman of the Board, a Vice-Chairman, and a Secretary, who shall be elected by the Trustees, from the members of the Board, by ballot to serve for a term of three years. All vacancies shall be filled by the Board for the unexpired term; provided, however, that the Executive Committee shall have power to fill a vacancy in the office of Secretary to serve until the next meeting of the Board of Trustees.

2. The Chairman shall preside at all meetings and shall have the usual powers of a presiding officer.

3. The Vice-Chairman, in the absence or disability of the Chairman, shall perform his duties.

4. The Secretary shall issue notices of meetings of the Board, record its transactions, and conduct that part of the correspondence relating to the Board and to his duties. He shall execute all deeds, contracts or other instruments on behalf of the corporation, when duly authorized.

Article IV.

EXECUTIVE ADMINISTRATION.

The President.

1. There shall be a President who shall be elected by ballot by, and hold office during the pleasure of, the Board, who shall be the chief executive officer of the Institution. The President, subject to the control of the Board and the Executive Committee, shall have general charge of all matters of administration and supervision of all arrangements for research and other work undertaken by the Institution or with its funds. He shall devote his entire time to the affairs of the Institution. He shall prepare and submit to the Board of Trustees and to the Executive Committee plans and suggestions for the work of the Institution, shall conduct its general correspondence and the correspondence with applicants for grants and with the special advisers of the Committee, and shall present his recommendations in each case to the Executive Committee for decision. All proposals and requests for grants shall be referred to the President for consideration and report. He shall have power to remove and appoint subordinate employees and shall be *ex officio* a member of the Executive Committee.

2. He shall be the legal custodian of the seal and of all property of the Institution whose custody is not otherwise provided for. He shall affix the seal of the corporation whenever authorized to do so by the Board of Trustees or by the Executive Committee or by the Finance Committee. He shall be responsible for the expenditure and disbursement of all funds of the Institution in accordance with the directions of the Board and of the Executive Committee, and shall keep accurate accounts of all receipts and disbursements. He shall submit to the Board of Trustees at least one month before its annual meeting in December a written report of the operations and business of the Institution for the preceding fiscal year with his recommendations for work and appropriations for the succeeding fiscal year, which shall be forthwith transmitted to each member of the Board.

3. He shall attend all meetings of the Board of Trustees.

Article V.

COMMITTEES.

1. There shall be the following standing Committees, viz., an Executive Committee, a Finance Committee, and an Auditing Committee.

2. The Executive Committee shall consist of the Chairman and Secretary of the Board of Trustees and the President of the Institution *ex officio* and, in addition, five trustees to be elected by the Board by ballot for a term of three years, who shall be eligible for re-election. Any member elected to fill a vacancy shall serve for the remainder of his predecessor's term: Provided, however, that of the Executive Committee first elected after the adoption of these by-laws two shall serve for one year, two shall serve for two years, and one shall serve for three years; and such Committee shall determine their respective terms by lot.

3. The Executive Committee shall, when the Board is not in session and has not given specific directions, have general control of the administration of the affairs of the corporation and general supervision of all arrangements for administration, research, and other matters undertaken or promoted by the Institution; shall appoint advisory committees for specific duties; shall determine all payments and salaries; and keep a written record of all transactions and expenditures and submit the same to the Board of Trustees at each meeting, and it shall also submit to the Board of Trustees a printed or typewritten report of each of its meetings, and at the annual meeting shall submit to the Board a report for publication.

4. The Executive Committee shall have general charge and control of all appropriations made by the Board.

5. The Finance Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

6. The Finance Committee shall have custody of the securities of the corporation and general charge of its investments and invested funds, and shall care for and dispose of the same subject to the directions of the Board of Trustees. It shall consider and recommend to the Board from time to time such measures as in its opinion will promote the financial interests of the Institution, and shall make a report at each meeting of the Board.

7. The Auditing Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

8. The Auditing Committee shall, before each annual meeting of the Board of Trustees, examine the accounts of business transacted under the Finance Committee and the Executive Committee. They may avail themselves at will of the services and examination of the Auditor appointed by the Board of Trustees. They shall report to the Board upon the collection of moneys to which the Institution is entitled, upon the investment and reinvestment of principal, upon the conformity of expenditures to appropriations, and upon the system of bookkeeping, the sufficiency of the accounts, and the safety and economy of the business methods and safeguards employed.

9. All vacancies occurring in the Executive Committee and the Finance Committee shall be filled by the Trustees at the next regular meeting. In case of vacancy in the Finance Committee or the Auditing Committee, upon request of the remaining members of such committee, the Executive Committee may fill such vacancy by appointment until the next meeting of the Board of Trustees.

10. The terms of all officers and of all members of committees shall continue until their successors are elected or appointed.

Article VI.

FINANCIAL ADMINISTRATION.

1. No expenditure shall be authorized or made except in pursuance of a previous appropriation by the Board of Trustees.

2. The fiscal year of the Institution shall commence on the first day of November in each year.

3. The Executive Committee, at least one month prior to the annual meeting in each year, shall cause the accounts of the Institution to be audited by a skilled accountant, to be appointed by the Board of Trustees, and shall submit to the annual meeting of the Board a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year.

4. The Board of Trustees, at the annual meeting in each year, shall make general appropriations for the ensuing fiscal year; but nothing contained herein shall prevent the Board of Trustees from making special appropriations at any meeting.

5. The securities of the Institution and evidences of property, and funds invested and to be invested, shall be deposited in such safe depository or in the custody of such trust company and under such safeguards as the Trustees and Finance Committee shall designate; and the income available for expenditure of the Institution shall be deposited in such banks or depositories as may from time to time be designated by the Executive Committee.

6. Any trust company entrusted with the custody of securities by the Finance Committee may, by resolution of the Board of Trustees, be made Fiscal Agent of the Institution, upon an agreed compensation, for the transaction of the business coming within the authority of the Finance Committee.

Article VII.

AMENDMENT OF BY-LAWS.

1. These by-laws may be amended at any annual or special meeting of the Board of Trustees by a two-thirds vote of the members present, provided written notice of the proposed amendment shall have been served personally upon, or mailed to the usual address of, each member of the Board twenty days prior to the meeting.

MINUTES

OF THE

EIGHTEENTH MEETING OF THE BOARD OF TRUSTEES

ABSTRACT OF MINUTES OF EIGHTEENTH MEETING OF BOARD OF TRUSTEES.

The meeting was held in Washington, in the Board Room of the Administration Building, on Friday, December 12, 1919, and was called to order at 10 a. m. by the Chairman, Mr. Root.

Upon roll call the following Trustees responded: John J. Carty, Myron T. Herrick, Charles L. Hutchinson, Henry Cabot Lodge, Andrew J. Montague, William W. Morrow, James Parmelee, Wm. Barclay Parsons, Stewart Paton, Henry S. Pritchett, Elihu Root, Theobald Smith, Charles D. Walcott, William H. Welch, George W. Wickersham, Robert S. Woodward.

The minutes of the seventeenth meeting were approved as printed and submitted to members of the Board.

The Secretary reported the death of Mr. Henry L. Higginson and the Trustees unanimously directed that suitable resolutions be placed in the Minutes concerning his death, with expressions of the profound regret of his associates on the Board of Trustees.

Reports of the President, the Executive Committee, the Auditor, the Finance Committee, and of Directors of Departments, Associates, and Research Associates of the Institution were presented and considered.

The following appropriations for the year 1920 were authorized:

Reserve Fund	$250,000
Insurance Fund	25,000
Pension Fund	40,000
Administration	55,000
Publication	60,000
Division of Publications	15,000
Departments of Research	882,316
Associates of Institution	25,900
Minor Grants	75,800
Index Medicus	17,200
Total	1,446,216

It was decided to hold an adjourned meeting of the Board of Trustees, in Washington, on January 24, 1920.

REPORT OF THE PRESIDENT

OF THE

CARNEGIE INSTITUTION OF WASHINGTON

FOR THE YEAR ENDING OCTOBER 31, 1919

REPORT OF THE PRESIDENT

OF THE

CARNEGIE INSTITUTION OF WASHINGTON.

In conformity with Article IV, section 2, of the By-Laws of the Carnegie Institution of Washington, the President has the honor to submit the following report on the work of the Institution for the fiscal year ending October 31, 1919, along with recommendations of appropriations for the ensuing year and with sundry suggestions concerning other matters of general or special interest.

This report is the seventeenth annual administrative report of the Institution and is presented under the following principal heads:

1. Salient events of the year.
2. Researches of the year.
3. Financial records.
4. Publications of the year.
5. Proposals for budget for 1920.
6. Bibliographical appendix.

SALIENT EVENTS OF THE YEAR.

Andrew Carnegie.

In the vast aggregate of phenomena of which man becomes more or less conscious, there are often observed remarkable coincidences and sequences. These must occur, indeed, by reason of fortuitous combinations of causes as well as by reason of causal connections, although it is rarely possible, outside the domains of the older sciences, to determine in any case whether the law of chance or the law of causation is chiefly concerned. Thus the past year which has witnessed the climax of the world's greatest national and international calamities has witnessed also the Institution's greatest losses by death; for the Founder, three of the initial

Trustees, and a Research Associate have died within the fiscal interval to which this report refers.

Andrew Carnegie, man of affairs, idealist, and philanthropist, was born at Dunfermline, Scotland, November 25, 1835, and died at his summer home, Lenox, Massachusetts, August 11, 1919. The history of his singularly active, diversified, and productive career is too well known in all its essentials to require restatement or elaboration here. His life was peculiarly open and transparent; and although some of his contemporaries have seemed prone to discover necromantic as well as romantic elements in his activities, few men have been so easy to understand and few have preached and practiced the homelier virtues of humanity with greater simplicity and sincerity and with greater personal and public advantage. His biography is, indeed, already recorded in surpassing degree in his achievements as a pioneer in American industries, in the remarkable legal instruments establishing his world-wide philanthropies, and in his published popular writings, wherein he has disclosed, with the utmost frankness, the ideas and the ideals which have served as guides to conduct in association with his fellow-men. It appears appropriate here, therefore, to mention only some of the less well-known facts concerning his relations to the Institution whose evolution he has watched with the liveliest interest and with a degree of patience attained rather rarely even by the founders and the best friends of such novel enterprises.

To understand and to appreciate Mr. Carnegie's attitude toward the Institution and his attitude in general toward the organizations he has endowed, it is essential to recall the maxims expressed in his deeds of trust to the altruistic organizations he has founded and the sentiments expressed by him frequently also in conversation concerning the administration of such establishments. In his deed to the Board of Trustees of the Institution, under date of January 28, 1902, there are, among many others, the following significant paragraphs:

"The Trustees shall have the fullest power and discretion in dealing with the income of the Trust, and expending it in such manner as they think best fitted to promote the objects set forth in the following clauses:

* * * * * * *

"The specific objects named are considered most important in our day, but the Trustees shall have full power, by a majority of two-thirds of their

number, to modify the conditions and regulations under which the funds may be dispensed, so as to secure that these shall always be applied in the manner best adapted to the changed conditions of the time."

In the deed of trust establishing the Endowment for the promotion of International Peace, under date of December 14, 1910, the same idea with respect to administration is stated with increasing emphasis:

"Lines of future action can not be wisely laid down. Many may have to be tried, and having full confidence in my Trustees I leave to them the widest discretion as to the measures and policy they shall from time to time adopt, only premising that the one end they shall keep unceasingly in view until it is attained, is the speedy abolition of international war between so-called civilized nations."

And finally, under date of November 10, 1911, in his deed founding the Carnegie Corporation of New York, this precept is given still more emphatic expression:

"Conditions upon the earth inevitably change; hence, no wise man will bind Trustees forever to certain paths, causes or institutions. I disclaim any intention of doing so. On the contrary, I give my trustees full authority to change policy or causes hitherto aided, from time to time, when this, in their opinion, has become necessary or desirable. They shall best conform to my wishes by using their own judgment."

Herein may be found the key to the relations Mr. Carnegie sustained to the Institution, and the principal key likewise to the successes he attained in the great industrial and philanthropic enterprises to which his energies were mainly devoted. He did not seek to dominate, or even to guide, his trustees. He suggested fields for exploration and cultivation; but he committed the more difficult details of elaboration and development, with the largest liberties, to those who could give them direct and continuous attention and assume accountability for the outcome. He was thus able at once to enlist the cooperation of superior coadjutors and to secure the prime requisites for administrative efficiency, namely, authority to act and coordinate responsibility.

Close adherence to this attitude on the part of Mr. Carnegie has been of the greatest advantage to the Institution. Initially it was a subject of the most varied and contradictory conjecture and expectation. In its earlier years it was often facetiously remarked that one might quote equally eminent opinion on all sides of every question concerning its possibilities. A vastly greater volume of excellent advice was available than could pos-

sibly be used. There were thus the amplest of opportunities for the generation of misunderstandings between the partisans of equally worthy but necessarily rival or conflicting interests; and a saving sense of humor, as well as great patience, was needed to enable one to see that all of the admirably desirable aims suggested could not be realized simultaneously. Inevitably, in spite of his theory and practice to the contrary, some of these conflicting interests were pressed by their advocates upon Mr. Carnegie for his decision. But he never deviated from the uniform practice of relegating all such matters for final determination to the Trustees of the Institution. He not infrequently expressed opinions, pro or con, with respect to questions under consideration, but he disclaimed authority and often cautioned his coadjutors against the dangers of personal bias on his part.

The rare wisdom of this liberal attitude toward a research establishment has been verified repeatedly in the history of the Institution. In the nature of things it was destined to venture into many undertakings that would appear debatable, or even hazardous, to those who had not given them special attention. Doubts, indeed, were entertained, properly enough, by Mr. Carnegie, and by many highly esteemed contemporaries, with regard to the practicability and the ultimate value of such projects as the Solar Observatory, the Geophysical Laboratory, the Magnetic Survey of the Earth, and the larger projects generally of the Institution. To those even whose duty appeared to require vigorous and sustained support for these undertakings there was an element of doubt, while there was a degree of hazard to those especially who planned them, in the possibility that sufficient time might not be granted to prove their feasibility and to justify their costs. That Mr. Carnegie, as well as other people, should entertain some misapprehensions in respect to the aims and details of these complex matters was, therefore, unavoidable. Thus, to cite a single example, which illustrates his characteristic frankness and fairness, shortly before the construction of the non-magnetic ship was authorized he requested an interview in respect to quite other affairs than those of the Institution. Before these were approached, however, he proceeded to remark emphatically, "I don't approve that project you are urging for a non-magnetic ship." "But," he

added, "maybe I don't understand it?" The opportunity thus gracefully extended was speedily utilized and Mr. Carnegie was readily convinced that the project in question was not one merely of an enthusiastic dreamer, but one based on the carefully verified calculations and plans of competent engineers.

It should be understood, however, that Mr. Carnegie's special interest in and confidence in the larger projects of the Institution did not depend to any great extent on explanations, on arguments, or on the results of the elaborate preliminary studies that have preceded all these developments. His sympathy and faith rested rather on the general induction from experience that discoveries and advances require boldness in concepts supplemented by untiring patience and persistence as well as by ample financial means. These projects appealed to his imagination in the same way that similar departures from precedent had appealed to him in the steel industry several decades earlier. In this latter connection he used to relate with great good humor how he was roused by an inquiry addressed to him by James B. Eads (about 1870) when the first great steel bridge across the Mississippi River, at St. Louis, was projected. Eads desired to learn whether Mr. Carnegie's company would undertake to supply steel bars having a much higher "modulus of elasticity" than had been previously attained. Mr. Carnegie promptly replied that an order for such steel would be accepted, and production speedily followed. In recounting this incident (in 1911) Mr. Carnegie explained that while he did not hold a very clear notion of the meaning of the term "modulus of elasticity," he was confident that one of his partners, who was a professional engineer and a pupil of the distinguished Rankine of the University of Glasgow, would know all the technicalities, and hence that it would be practicable for his company to fill the order if it could be filled at all.

Throughout the history of the Institution Mr. Carnegie has been deeply solicitous for its financial stability and continuity. Thus, in 1907, when accumulated and current income was approaching absorption in the rapidly expanding work undertaken, he recognized the need of additional funds and increased the Institution's endowment by $2,000,000. But in doing so he administered a rational caution against the dangers of such

extravagances as result only in buildings whose value is chiefly architectural. This was a critical period, since opinion was still somewhat divided on the very practical question whether the Institution should conduct its work directly, or indirectly by acting mainly as a disbursing office for other agencies. Counsels were even more divided on the equally practical question whether the Institution should have a specially designed home for its administrative staff and storage-room for its publications, or whether it should continue to rent such quarters as could be found. While Mr. Carnegie did not take sides strongly in these controversial matters, he departed from his usual custom to the extent of addressing a letter to the President calling attention especially to the protests of those who thought it unessential to construct the Administration Building in Washington. But this letter is closed by the following sentence: "As an antidote to this I inclose a note, and with sincere congratulations on the success already achieved by you, I am always very truly yours." The "note" was the following letter:*

NEW YORK, *December 4, 1907.*

DEAR SIR: I have watched the progress of the Institution under your charge and am delighted to tell you that it has been such as to lead me to add two millions of dollars more to its endowment.

It has borne good fruit and the Trustees are to be highly congratulated. In their hands and yours I am perfectly satisfied it is going to realize not only our expectations, but our fondest hopes, and I take this opportunity to thank one and all who have so zealously labored from its inception.

Very truly yours,

ANDREW CARNEGIE.

Dr. R. S. WOODWARD,
President, Carnegie Institution,
Washington, D. C.

Again, in November 1910, when called to consult with him about another subject, he announced that as soon as he could arrange the preliminaries he would increase the endowment of the Institution by $10,000,000. He added that the main reason which led him to this decision was that the Institution had proved capacity to live within income. Formal tender of this gift was made in his letter to the Trustees of January 19, 1911, published in full in the Year Book of that year. An important stipulation in this remarkable letter required setting apart

* Hitherto unpublished so far as the writer is aware.

annually, for a period of a decade, one-half of the income of this addition to endowment, as a reserve fund "against losses, emergencies, reduction in income, and the diminishing purchasing power of money."

His interest in the work of the Institution continued to the end. His last signed letter to the President, dated September 27, 1918, begins with the characteristic sentence: "Your very kind letters reporting from time to time the progress of the Institution give me rare pleasure." He was especially glad to learn of the numerous ways in which the Institution and its staffs were able to assist the United States Government during the world war. That our archeologists, biologists, historians, philologists, and other specialists should be called into service; that the Geophysical Laboratory should undertake the manufacture of optical glass; that the Mount Wilson Observatory should engage to construct optical adjuncts for artillery, or that the Department of Terrestrial Magnetism should be able to render technical aid to the Army and the Navy, furnished an unexpected and impressive experience to him as well as to others not intimately acquainted with the details of these affairs. Even as late as June 1919, about two months before his death, when his strength was evidently rapidly waning, he was eager to learn of the latest developments of what he familiarly called the "Research Commission." His idealism was still as dominant as it was when he expressed the hope in his letter to the Trustees of January 19, 1911, referred to above, that "the work on Mount Wilson will be vigorously pushed, because I am so anxious to hear the expected results from it. I should like to be satisfied, before I depart, that we are going to repay to the old land some part of the debt we owe them by revealing more clearly than ever to them the new heavens." He did not live to realize this hope. The world war postponed, for nearly two years, the use of the 100-inch telescope, in which he was particularly interested, so that the results he anticipated from it are only now beginning to appear. But he was content, as indeed all of his contemporary Trustees must be content, with the reflection that the best work of the Institution is not so much for the present and for us as for the future and for our successors.

A complete list of the men who have thus far been connected with the Institution in the capacity of Trustee embraces 51 names. Of these, 6 were members ex officio, during the years 1902 and 1903, under the terms of the original charter. Of this total number, 23 are now deceased; and of the initial Trustees, 27 in number, including members ex officio, only 7 remain. Those who, during the year just ended, have passed on to increase the majority of this initial company are Andrew Dickson White, Theodore Roosevelt, and John Coit Spooner. All of these men are so well known and so highly esteemed that it would be a work of supererogation to make mention of them here except for the probability that in the multitude of their national services the fact that they were among the builders of the Institution might be overlooked. The procession of current events is fatefully swift, and we are constantly in danger of forgetting our obligations to the dead while seeking to fulfil our obligations to the living.

Deceased Trustees.

Andrew Dickson White was born at Homer, New York, November 7, 1832, and died at his home in Ithaca, New York, November 5, 1918. The history of his remarkable career as student, teacher, author, university administrator, legislator, diplomatist, man of letters, and man of the world, has been very fully recorded in his admirable autobiography published in 1905.* His richly varied experience in all these departments of life gave him an uncommon equipment for consideration of the questions which arose at the foundation of the Institution. Although nearly 70 years of age when he became a Trustee, he continued to serve in this capacity with the keenest of interest and unfailing regularity for 15 years, resigning only when the infirmities of age prevented him from attending the meetings of the Board of Trustees. During the early part especially of the present administration he was a counsellor of rare value. The difficulties and the dangers which beset the Institution were in many respects similar to what he called the "rocks, storms, and peril" encountered by him in the early development of Cornell University. He was therefore a very sympathetic as well as a very competent adviser concerning the courses that might be

* The Century Company, New York, N. Y.

followed with safety by the new establishment. As an eminent historian he knew well the tangled array of favorable and unfavorable precedents set up by mankind in the slowly upward processes of development; as an accomplished man of the world he knew well the rules for application of appropriate corrections for personal equation; and to these and other capital qualifications of a counsellor he added an outlook of confident optimism, seldom manifested by a septuagenarian, toward all that makes for rational progress. He lived a long and uncommonly fruitful altruistic life, noteworthy throughout for its happy combination of the enthusiasm of youth with the wisdom of age.

Theodore Roosevelt, twenty-sixth President of the United States, was born at New York City, October 27, 1858, and died at his home at Oyster Bay, Long Island, New York, January 6, 1919. At the time of his death he was probably the most widely known and the best understood of Americans. He was by nature a public character in the best sense of the phrase. Like Mr. Carnegie, he may be said to have capitalized the more familiar virtues. He was a modern apostle of the golden rule, or of the "square deal"; and he won his way to public position by the generation of universal confidence in his integrity. He was a bold champion of the "merit system" and an implacable foe of "invisible government." He was, along with Washington, Jefferson, and Franklin, among the regrettably small number of American statesmen who have shown any considerable acquaintance with, or just appreciation for, that sort of learning called scientific. Like Andrew D. White, he was one of those broader, though relatively rare, humanists who have adequately estimated the significance of the modern doctrine of evolution.

Mr. Roosevelt was a member ex officio of the Board of Trustees during the years 1902–1904, under the terms of the original charter, which gave to the Institution a quasi-governmental connection. It does not appear from the official records that he found time, in the strenuous life he then led, to attend any of the meetings of the Board. His sole but important part in the recorded history of the Institution consists in his official approval of the act of incorporation granted by the Congress of the United States under date of April 28, 1904.

John Coit Spooner, distinguished lawyer and ex-Senator of the United States, was born at Lawrenceburg, Indiana, January 6, 1843, and died at New York City, June 11, 1919. He was one of those virile Americans who were disciplined in the great Civil Conflict of 1861–1865 and who have figured so prominently, if not predominantly, in all national developments of the fifty years following that war. He was conspicuous for his independence and courage in the political life of his times. During his long term of 16 years of service as Senator he displayed remarkable constructive capacity, especially in dealing with the legislative problems resulting from the Spanish-American war and from other national and international complications following that disturbed period. Like all his colleagues of the Board of Trustees, he was busily preoccupied with other affairs; and it is not surprising that along with a few others he should not have found time to take a very active part in the administrative proceedings of the Institution. He regretted this fact, and on resigning his senatorship, in 1907, in order that he might resume the arduous tasks of his profession, he relieved himself also of the duties of his trusteeship.

W. Max Müller, eminent orientalist and a Research Associate of the Institution since 1904, was born at Gliessenburg, Germany, May 15, 1862, and died from drowning at Wildwood Crest, New Jersey, July 12, 1919. He was an indefatigable student of Egyptology and made three archeological expeditions under the auspices of the Institution to that country. He was one of the last to make competent observations on some of the temples of the upper Nile. His studies at Philæ, especially, present him as a pathetic figure seeking to save from oblivion the inscriptions on those ancient temples when the waters of the Assouan Dam were gradually rising to obliterate them. Thus, in a letter to Dr. S. Weir Mitchell dated September 26, 1910, Dr. Müller writes:

"I am sitting on the highest temple tower of Philæ and looking down on the rocky island, on the wonderful scenery along the Nile, and on the incomparably beautiful temple. What a charming place! All out of the water now, the temple seems to be in a better state of repair than ever; even a little green vegetation of desert character now spreads over the island, once so green with trees and shrubs, but now having only three date palms left. It is as though Philæ appeared once more before its death, a coquette with the

'face of Hippocrates' and yet painted and adorned to deceive the public and to catch a last glimpse of admiration. How beautiful is everything! In the distance, however, I see its doom, the fatal dam of Assouan, and I hear the roaring of the floods passing through it. The rocky islands of Bigeh and Konosso frame this picture, to the east a few verdant fields ashore and the miserable little railway and steamer station Shellal. If it were not so very lonely, it would be more beautiful here. I am absolutely alone on the deserted island. My servant uses every pretext to go to Assouan; he forgets things, I fear, only to have another chance of crossing the Nile. The Nubian guard of the Temple is rarely seen; he mostly is over on Bigeh with his family, and he rows over to Philæ only when he sees a boat coming to the island. Thus it is a perfect hermit life I am leading now."

Reports of Dr. Müller's researches in Egypt have been given in publication No. 53, volumes 1 and 2, while a third volume, bearing the title "The Two Bilingual Decrees of Philæ," is now nearly ready to issue. This latter was in press at the time of his premature death. Fortunately for him and for this work the sympathetic and critical aid of his friend and colleague, Dr. H. F. Lutz, has been secured to complete this volume and to add it to the enduring contributions the author had already registered for himself in the world of scholarship.

Emergence from War.

When the armistice was agreed to by the contending nations in November 1918, the Institution had become more of an agency for the promotion of warfare than one for the promotion of peaceful pursuits. About two-thirds of the staffs connected directly with the Institution, or somewhat more than 200 men, were engaged in war work, and about the same proportion applies to the Research Associates of the Institution and their collaborators. Nearly every expert of the Institution was able to render assistance and many of them devoted their entire time and energies to Government work. Of the larger undertakings in this work, the most conspicuous are the development to the point of quantity production of the optical glass industry by the Geophysical Laboratory; the manufacture of precision micrometers for the U. S. Bureau of Standards and the manufacture of optical adjuncts for artillery by the staff of the Mount Wilson Observatory; the construction of special devices for the Navy in the shops of the Department of Terrestrial Magnetism; the contributions of the Nutrition Laboratory to knowledge of the effects of undernutrition; and the information service rendered

by the Department of Historical Research. These undertakings required many men in arduous researches and involved no inconsiderable costs to the Institution, since it assumed, in most cases, the principal overhead expenses. Not less important relatively than these larger operations were many special and individual contributions to the general cause. That essential occupations were quickly developed for what are sometimes called "narrow specialists" in nearly every branch of learning cultivated by the Institution affords striking evidence at once of the diversity of modern warfare and of the ultimate practical value of recondite researches.

Although formal requests from the Government for services ceased nominally toward the close of the calendar year 1918, they actually continued until nearly the middle of 1919. Thus, the optical work and the researches on the concentration of nitrates for the War Department did not end until June 1919; the information work of the Department of Historical Research continued until mid-July; some special work for the Navy was done by the Department of Terrestrial Magnetism as late as September of this year; while a few other relations in Government undertakings still remain to be severed. It is only recently, also, that members of the Institution in the military and other services of the Government have returned to their posts; so that emergence from the untoward conditions in which we find ourselves has only fairly begun.

Naturally, this deflection of interest from the normal activities of the Institution has led to many changes, to some dislocations, and to the suspension, or even abandonment, of a number of projects. The war, in fact, has brought some sinister consequences to the Institution as well as to most other organizations. Fortunately, of those who entered the military and naval service only two lives were lost, namely, Karl Edward Anderson and Billings Theophilus Avery, both of the Department of Experimental Evolution, who died during the year 1918. Fortunately, likewise, while some members of the investigatory staffs of the departments of research have been drawn off, by reason of their abilities, into industrial or other occupations, the number of such is not only small but not in excess of an inevitable and

healthy exchange between a progressive establishment and its contemporaries.

Detailed reports concerning the war activities of the Institution, and particularly concerning the work done by the departments of research, are on file in the office of administration; so that if it should become necessary to publish an account of these activities the essential data are at hand. The time for publication of such an account does not appear to have arrived, since the Government is entitled to initiative and priority in all these matters.* Hence only the briefest references to them are made in this and other parts of the current Year Book.

It should go without saying that the disturbed conditions, social, industrial, economic, and governmental, under which the world is now laboring are not without untoward effects on the Institution. Being a part of and not apart from contemporary life, it must share to a greater or less extent in the consequences which follow from an unparalleled attempt at national supremacy based on the desperate doctrine of "dominance or downfall." But obvious as these consequences are in the abstract, there appear to be many outside and some within the Institution who think that it may continue to expand regardless of the limits of its income and regardless of the fact that the purchasing capacity of this income has diminished by one-half during the past decade. In line with these vagaries there is a recrudescence also of the juvenile notion so commonly held of the Institution in its earlier years, that it may play the rôle of paternalism for other establishments and for individuals, and that it may act generally as a salvager in the wreckage of the world. Similarly, just as in political affairs it is often assumed that the prevailing scarcity of necessities and the burdens of taxation may be relieved by other means than by productive labor, so it is assumed that the Institution may meet the increasing costs of its operations, not by appropriate restrictions and economies, but by increasing appropriations drawn from mythical sources. Thus the distribution of necessary disappointment, which has been so large a part of the unproductive business of the administrative

* A concise history of the production of optical glass is given by Dr. Fred E. Wright (major Engineer Corps, U. S. A.), of the staff of the Geophysical Laboratory, in "America's Munitions," published by the War Department in 1919.

office hitherto, is now increasing, stimulated by two generations of men unaccustomed to the practice of thrift and justified by the widely prevalent but immoral theory that the Institution may proceed "regardless of expense."

The Hooker Telescope.

One of the distinct, if relatively unimportant, misfortunes of the world war was the delay in testing the capacities of the 100-inch telescope named after Mr. John D. Hooker, of Los Angeles, who made the initial contribution toward the construction of this instrument thirteen years ago. It was substantially completed shortly before the United States became a participant in the conflict. About this time, also, the Director of the Observatory became chairman of the National Research Council and he continued to give all his time to this governmental organization until May of this year. In the meantime, likewise, as already indicated, the staff of the Observatory was preoccupied largely with military rather than with astronomical affairs. Hence, opportunity has only recently arrived for determination of the critical question whether this "largest telescope," which is 28 inches larger than its largest predecessor, and 40 inches larger than the highly successful 60-inch instrument completed by the Observatory in 1908, would meet expectations in optical capacity and practicability of operation. The construction of so large a telescope has been regarded as one of the hazardous undertakings of the Institution. Its optical perfection depends on the stability of the glass used for its mirror; the stability of the latter depends in turn on the rigidity of its mountings; the requisites in both cases must take into account the elastic mobility of materials and the disturbing effects on them of temperature changes; and all these considerations must unite to secure a combination which is manageable. The problems in engineering thus presented have appealed very strongly to all parties interested in such constructions, perhaps almost as strongly as the astronomical possibilities anticipated from such an extensive addition to visual apparatus. But the Director of the Observatory now reports that the optical and the engineering difficulties have been overcome and that the instrument under

repeated tests has proved efficient quite beyond the conservative theoretical predictions of attainable capacities.

The Non-Magnetic Ship.

As related in the report of the preceding year, it was deemed expedient, in April 1917, on account of dangers to navigation, to suspend the cruise contemplated by the Department of Terrestrial Magnetism for additional surveys in the Atlantic Ocean by the ship *Carnegie*. As related also in that report, this ship was brought safely, by way of the Pacific Ocean and the Panama Canal, to the port of Washington, District of Columbia, arriving there June 10, 1918. She lay here until the spring of 1919, when it was decided to send her out again on her mission as soon as necessary repairs and alterations could be made. Of the alterations required, the most important was the adaptation of her engine for auxiliary propulsion to the use of gasolene as fuel. When this ship was launched, in 1909, it was easier to get anthracite coal than gasolene or other liquid fuel in remote parts of the world. Hence the engine was constructed to use gas derived from such coal by the so-called producer process. In the meantime, anthracite coal has become much less and gasolene much more accessible at distant seaports, and this circumstance has led to the noteworthy, and in these times expensive, but highly advantageous change here specially referred to. After delays which serve to emphasize the inefficiency of mankind under post-war conditions, on October 19, the *Carnegie*, under the command of Mr. J. P. Ault, put to sea from the Virginia Capes, on her sixth cruise, to comprise surveys in the Atlantic and Indian Oceans not yet adequately covered by previous circuits.

Publications of the Year.

Of all branches of the Institution the one least affected by the war is the Division of Publications. Although it has undergone some changes in staff and encountered the obstacles due to a rapid rise in the costs of printing and illustrations, its work has gone on without serious interruption; and the output of books for the year, as may be seen by reference to the detailed list given in a later section of this report, is rather greater than the average annual output for the past decade. Of the entire list of twenty-nine

volumes issued, only two classes of them, selected mainly for the purpose of showing trends of progress, may be referred to here.

The most elementary, the most essential, and hence the most widely used, if not esteemed, of the sciences is arithmetic. It is a fundamental requisite, in fact, of all exact knowledge. Ability to add, subtract, multiply, and divide affords probably the simplest test of capacity for correct thinking. Conversely, inability or indisposition to make use of these simple operations affords one of the surest tests of mental deficiency, as witnessed, for example, by numerous correspondents who are unable to or who refuse to apply these operations to the finances of the Institution. But the familiar science of arithmetic lies at the foundation also of a much larger and a far more complex structure called the theory of numbers. This theory has been cultivated by many of the most acute thinkers of ancient and modern times. It has more points of contact with quantitative knowledge in general than any other theory except the theory of the differential and integral calculus. These two theories are complementary, the first dealing with discrete or discontinuous numbers and the second with fluent or continuous numbers. Naturally, a subject which has attracted the attention of nearly all of the great mathematicians of the past twenty centuries has accumulated a considerable history. The more elementary contributions of Euclid, Diophantus, and others of the Greek school; the extensions of Fermat, Pascal, Euler, Newton, Bernoulli and many others in the seventeenth and the eighteenth centuries; and the work of Lagrange, Laplace, Gauss, and their numerous contemporaries and successors of the nineteenth century, make up an aggregate which has stood hitherto in need of clear chronological tabulation and exposition. This laborious task was undertaken about ten years ago by a Research Associate of the Institution, Professor Leonard E. Dickson, of the University of Chicago. A publication under the title "History of the Theory of Numbers" has resulted, and volume I (8vo, xii + 486 pp.), devoted to divisibility and to primality of numbers, has appeared during the past year; and a second volume devoted to diophantine analysis is now in press. This work is remarkable for its condensation of statement. It contains more information per unit area than any other work issued

thus far by the Institution. It is remarkable also for the care taken by the author and by his collaborators to secure precision and correctness, a number of experts having assisted in the arduous labors of verification required during the process of printing.

It is the object of science primarily to find answers to the question "How?" rather than to the question "Why?"; or, to seek to describe phenomena rather than to try to explain them. Words, however, constitute, in general, a rather imperfect medium for the communication of ideas, and as a consequence the intellectual world, like the political world, often finds itself involved in misunderstandings which lead to nothing better than that metaphorical and degenerate form of energy called the heat of controversy. Thus, about a half-century ago there arose, as we now see, a quite needlessly bitter discussion over the question whether and to what extent the phenomena of life may be traced back to the properties of matter with which they are obviously intimately associated. The new science of biology was just then arising and the limitations of its domain and the conditions of its existence and development were widely disputed, as is best shown probably by the lay sermon of Huxley, delivered at Edinburgh, November 8, 1868, "On the Physical Basis of Life." In this remarkable address Huxley defines, with prophetic clearness and completeness, the limitations and the conditions in question and these, as he defined them, are now generally admitted as essential to all fruitful inquiry. Moreover, the principles expounded by Huxley have been justified in amplest measure by the extraordinary progress since accomplished, not only in biology, but in all the physical sciences.

It is a good fortune for a research establishment to have been founded during the course of this progress and to be able to take part in it; and although the publications of the Institution are not restricted to any domain of learning, a considerable number of them bear directly or indirectly on this profoundly interesting and increasingly important problem of "the physical basis of life." The past year has been unusually productive in this line, for no less than a dozen volumes have been added to the Institution's series of contributions to evolution, heredity, and the application of thermodynamics to the interpretation of

metabolism in man. These contributions are particularly noteworthy also for the extent to which cooperation has been required, since more than twenty authors and more than twice that number of collaborators are represented in the dozen volumes referred to.

Plans for Retirement and Insurance.

The desirability of making provision for retirement on account of age or other disability for members of the staffs of the Institution has been under consideration for several years. A definitive plan for this purpose was approved by the Trustees at their meeting of December 14, 1917; it was made applicable by action of the Executive Committee April 11, 1919; and it became effective July 1, 1919.

The plan in question is drawn in conformity with the comprehensive system of the Teachers Insurance and Annuity Association of America and is to be administered in cooperation with that organization. A pamphlet setting forth in detail the conditions of applicability of the plan to members of the Institution has been published and distributed during the year, so that its general features need only be mentioned here. These consist of two provisions which are separate and distinct from one another, namely: (1) for annuities payable after retirement from active service, and (2) life insurance, purchasable by the beneficiary at cost from the Teachers Insurance and Annuity Association of America.

(1) Annuities are provided by means of equal annual contributions from the annuitants and from the Institution; each contributing in any case 5 per cent of the individual's salary, the amount of the latter used in computations for any year being the amount on the first of January of that year. In this cooperation the Institution assumes the overhead expense of administration.

(2) Provision for life insurance, on the other hand, under the specially favorable terms accorded to members of the Institution, rests wholly with the individuals concerned, although the office of administration stands ready to make such division of any member's salary as he may direct in order to facilitate payments on account of life insurance.

The inauguration of such a measure at the present epoch would appear to be both appropriate and opportune. Its adoption assumes that the Institution may continue indefinitely, and it recognizes the value of foresight and thrift at a time when these more obvious essentials to rational existence are quite too commonly overlooked. The world has recently spent, if not wasted, a large share of its reserves and there appears to be no way to replace them except the old ways of production and economy. Conferences, legislation, and a redistribution of supplies and responsibilities may help; but the main source of relief is to be found in the individual practice of industry, prudence, and frugality. The success of this measure, therefore, will depend, plainly, on the continuity of the Institution and on the recognition by trustees and members therein of the principles of reciprocity and probability founded on centuries of experience and fortified by the demonstrations of indubitable mathematical theory.

RESEARCHES OF THE YEAR.

It has been sufficiently indicated in the preceding section and in the report of a year ago that the programs of the Departments of Research and of the Research Associates of the Institution have been, in most cases, materially deranged by the exigencies of national defense. Most investigations under way or projected have been delayed or suspended and few new projects not requisite to emergencies have been started. Nevertheless, much work under way prior to the war has been completed, and nearly all of the more important researches interrupted have been conserved to such an extent that they may be resumed as soon as the world returns to conditions more nearly peaceful than those now prevalent. It is surprising as well as gratifying that the departments of research, whose staffs have been drawn on heavily for quite other occupations than those to which they are severally devoted, have maintained their organizations without serious impairment; while in a number of cases they have had the good fortune to continue and to intensify their specialties in order to render effective aid to the Government. The experience of the Division of Research Associates is not quite so fortunate, since a considerable number of important

investigations have had to be wholly suspended while the individuals having them in charge and their more narrowly limited numbers of assistants have been attached to the various branches of the Government service. In most cases, however, it will be practicable to resume these researches as soon as national and international conditions will permit.

Following the precedents of the past two years the reports of the Directors of Departments of Research and of Research Associates are printed as usual in the current Year Book and are confined strictly to the work proper of the Institution. Special reports from the Departments of Research as to war activities have been filed in the Office of Administration, but their contents are reserved for such disposition as may be deemed fitting by the Board of Trustees at a later date.

FINANCIAL RECORDS.

Financial Statement for Fiscal Year 1918–1919.

The sources of funds available for expenditure during the past fiscal year, the allotments for the year, the revertments made during the year, and the balances unalloted at the end of the year are shown in detail in the following statement:

Financial Statement for fiscal year 1918–1919.

Object of appropriation.	Balances unallotted Oct. 31, 1918.	Appropriation Dec. 13, 1918.	Revertments Nov. 1, 1918, to Oct. 31, 1919.	Totals for fiscal year.	Aggregates of allotments and amounts transferred.	Balances unallotted Oct. 31, 1919.
Large grants	....	$918,490	$37,809.44	$956,299.44	$956,299.44	....
Minor grants	$8,204.10	116,640	36,396.06	161,240.16	156,840.06	$4,400.10
Publication	8,603.65	60,000	11,189.90	79,793.55	70,593.43	9,200.12
Administration	....	55,000	5,000.00	60,000.00	60,000.00	....
Reserve fund	....	250,000	....	250,000.00	250,000.00	....
Insurance fund	....	25,000	....	25,000.00	25,000.00	....
Pension fund	....	40,000	....	40,000.00	40,000.00	....
Total	16,807.75	1,465,130	90,395.40	1,572,333.15	1,558,732.93	13,600.22

Receipts and Expenditures of the Institution to Date.

The aggregates of receipts from interest on endowment, from interest on bond investments, from interest on deposits in banks, from sales of publications, from refunds on grants, and from miscellaneous sources, for each year since the foundation of the Institution, are shown by the following table; the grand total of these to date is $17,501,356.75.

Aggregates of financial receipts.

Year ending Oct. 31.	Interest on endowment.	Interest on bonds and bank deposits.	Sales of publications.	Refund on grants.	Miscellaneous items.	Total.
1902..	$250,000.00	$9.70	....	....	$1,825.52	$251,835.22
1903..	500,000.00	5,867.10	$2,286.16	....	101.57	508,254.83
1904..	500,000.00	33,004.26	2,436.07	$999.03	....	536,439.36
1905..	500,000.00	25,698.59	3,038.95	200.94	150.00	529,088.48
1906..	500,000.00	27,304.47	4,349.68	2,395.25	19.44	534,068.84
1907..	500,000.00	22,934.05	6,026.10	2,708.56	15.22	531,683.93
1908..	550,000.00	17,761.55	7,877.51	25.68	48,034.14	623,698.88
1909..	600,000.00	14,707.67	11,182.07	2,351.48	103,564.92	731,806.14
1910..	600,000.00	10,422.78	10,470.25	1,319.29	54,732.45	676,944.73
1911..	975,000.00	14,517.63	10,892.26	4,236.87	923.16	1,005,569.97
1912..	1,100,000.00	31,118.41	11,496.13	1,658.88	96,035.01	1,240,308.42
1913..	1,103,355.00	46,315.60	12,208.66	3,227.53	345,769.95	1,510,876.74
1914..	1,105,084.17	59,298.63	11,402.40	7,819.70	577,305.77	1,760,910.67
1915..	1,100,375.00	67,888.31	10,297.79	8,322.87	28,162.79	1,215,046.76
1916..	1,100,375.00	83,626.38	12,544.16	1,450.12	153,204.40	1,351,200.06
1917..	1,100,408.75	100,702.60	11,921.35	32,950.22	179,611.97	1,425,594.89
1918..	1,110,427.45	120,464.02	9,921.00	39,833.23	255,354.60	1,536,000.30
1919..	1,112,441.25	138,700.73	12,837.58	53,549.98	214,498.99	1,532,028.53
Total.	14,307,466.62	820,342.48	151,188.12	163,049.63	2,059.309.90*	17,501,356.75

* Of this amount $1,394,335 came from the sale of bonds in 1908, 1909, 1910, 1912, 1913, 1914, 1915, 1916, 1917, 1918; $51,265.74 from the Colburn Estate in 1916; and $580,000 from the Carnegie Corporation of New York in 1917, 1918, and 1919.

The following list shows the departments and divisions to which appropriations have been made by the Trustees and the amounts allotted by the Executive Committee during the year:

Department of Botanical Research	$49,290.00
Ecological Research	22,500.00
Department of Embryology	36,280.00
Eugenics Record Office	26,836.00
Department of Experimental Evolution	69,074.00
Geophysical Laboratory	119,209.44
Department of Historical Research	39,700.00
Department of Marine Biology	21,530.00
Department of Meridian Astrometry	34,816.00
Nutrition Laboratory	44,390.00
Division of Publications	15,000.00
Mount Wilson Observatory	159,264.00
Department of Terrestrial Magnetism	201,510.00
Aggregate for Minor Grants	130,116.62
Aggregate for Publications	70,593.43
Total	1,040,109.49

The purposes for which funds have been appropriated by the Board of Trustees of the Institution may be summarily classified under five heads: (1) Investments in bonds; (2) large projects; (3) minor projects, special projects, and research associates and assistants; (4) publications; (5) administration. The following

table shows the actual expenditures under these heads for each year since the foundation of the Institution:

Purposes for which funds have been appropriated.

Year ending Oct. 31.	Investments in bonds.	Large projects.	Minor projects, special projects, research associates, and assistants.	Publications.	Administration	Total.
1902	....	....	$4,500.00	....	$27,513.00	$32,013.00
1903	$100,475.00	....	137,564.17	$938.53	43,627.66	282,605.36
1904	196,159.72	$49,848.46	217,383.73	11,590.82	36,967.15	511,949.88
1905	51,937.50	269,940.79	149,843.55	21,822.97	37,208.92	530,753.73
1906	63,015.09	381,972.37	93,176.26	42,431.19	42,621.89	623,216.80
1907	2,000.00	500,548.58	90,176.14	63,804.42	46,005.25	702,534.39
1908	68,209.80	448,404.65	61,282.11	49,991.55	48,274.90	676,163.01
1909	116,756.26	495,021.30	70,813.69	41,577.48	45,292.21	769,460.94
1910	57,889.15	437,941.40	73,464.63	49,067.00	44,011.61	662,373.79
1911	51,921.79	463,609.75	63,048.80	37,580.17	45,455.80	661,616.31
1912	436,276.03	519,673.94	103,241.73	44,054.80	43,791.13	1,147,037.63
1913	666,428.03	698,337.03	110,083.06	53,171.59	43,552.89	1,571.572.60
1914	861,915.73	817,894.52	107,456.05	44,670.55	44,159.54	1,876,096.39
1915	206,203.21	770,488.58	109,569.37	46,698.56	48,224.04	1,181,183.76
1916	473,702.70	638,281.41	99,401.26	73,733.38	49,454.08	1,334,572.83
1917	505,473.49	695,813.07	97,526.69	62,884.61	48,766.29	1,410,464.15
1918	528,815.55	693,780.00	*170,220.74	44,394.83	49,118.76	1,486,329.88
1919	438,960.29	845,123.82	†203,810.84	68,964.23	55,742.83	1,612,602.01
Total	4,826,139.34	8,726,679.67	1,962,562.82	757,376.68	799,787.95	17,072,546.46

* Of this amount $45,000 came from the Carnegie Corporation of New York.
† Of this amount $75,000 came from the Carnegie Corporation of New York and $5,438.94 from the Pension fund.

Investments in Property. On account of site for and construction of the Administration Building of the Institution, and on account of real estate, buildings, and equipments of departmental establishments, the following sums have been expended since the foundation of the Institution:

*Schedule of real estate, equipments, and publications.**

Administration:		
Building, site, and equipment		$337,312.97
Department of Botanical Research (Sept. 30, 1919):		
Buildings and grounds	$31,816.94	
Laboratory and library	17,869.27	
Operating appliances	17,331.04	
		67,017.25
Eugenics Record Office (Sept. 30, 1919):		
Library, furniture, and operating appliances	11,696.63	
Archives	45,368.52	
Buildings and land	130,033.82	
		187,098.97
Department of Experimental Evolution (Sept. 30, 1919):		
Buildings, office, library, and grounds	126,051.77	
Laboratory apparatus	10,669.42	
Field	20,396.72	
		157,117.91

* Real estate and equipment, original cost.

Geophysical Laboratory (Sept. 30, 1919):		
Building, library, operating appliances	$169,373.86	
Laboratory apparatus	75,000.03	
Shop equipment	10,888.36	
		$255,262.25
Department of Historical Research (Sept. 30, 1919):		
Office	2,575.72	
Library	3,926.55	
		6,502.27
Department of Marine Biology (Sept. 30, 1919):		
Vessels	31,180.43	
Buildings, docks, furniture, and library	12,120.36	
Apparatus and instruments	8,745.30	
		52,046.09
Department of Meridian Astrometry (Sept. 30, 1919):		
Apparatus and instruments	2,453.41	
Operating	2,146.37	
		4,599.78
Nutrition Laboratory (Sept. 30, 1919):		
Building, office, and shop	120,854.54	
Laboratory apparatus	24,546.09	
		145,400.63
Mount Wilson Observatory (Aug. 31, 1919):		
Buildings, grounds, road, and telephone line	174,748.22	
Shop equipment	37,533.51	
Instruments	422,056.26	
Furniture and operating appliances	134,679.57	
Hooker 100-inch reflector	516,903.30	
		1,285,920.86
Department of Terrestrial Magnetism (Sept. 30, 1919):		
Building, site, and office	145,391.62	
Vessel and survey equipment	145,730.18	
Instruments, laboratory, and shop equipment	80,686.99	
		371,808.79
Publications:		
Stock on hand at sale price (Oct. 31, 1919)	292,272.45	
Outstanding accounts (Oct. 31, 1919)	2,686.91	
		294,959.36
		3,165,047.13

Expenses of Maintenance of Administration Building.

The cost of maintenance of the Administration Building, including the items of fuel, lighting, janitorial services, maintenance of grounds, repairs, and other incidental expenses, has been, for 1910, $2,981.65; for 1911, $2,641.53; for 1912, $2,919.89; for 1913, $2,601.15; for 1914, $3,251.08; for 1915, $3,955.60; for 1916, $2,870.51; for 1917, $3,272.50; for 1918, $3,891.80, and for 1919, $3,834.38.

PUBLICATIONS.

Publications Authorized and Issued during the Year.

The publication of 22 volumes has been authorized by the Executive Committee during the year, at an aggregate estimated cost of $59,200.00. The following list gives the titles and names of authors of the publications issued during the year; it includes 29 volumes, with an aggregate of 5,834 octavo pages and 2,431 quarto

pages. Of the 29 volumes, three were new editions of former books which had become out of print and were reproduced by photographic processes. Thirty additional volumes are now in press.

List of publications issued during the year.

Year Book, No. 17, 1918. Octavo, xvi+331 pages, 1 plate, 3 figures.

Photographic reproductions of Year Books Nos. 1 and 2, for the years 1902 and 1903, respectively, 721 pages, octavo.

Index Medicus, Second Series, Vol. 16, 1918. Octavo, 929 pages.

Index Medicus, War Supplement. Octavo, 262 pages.

No. 100. Ward, William Hayes. The Seal Cylinders of Western Asia. Reprint. Quarto, xxix+428 pages, 1,500 figures.

No. 248. Britton, N. L., and J. N. Rose. The Cactaceæ. Descriptions and Illustrations of Plants of the Cactus Family. Quarto, Vol. 1, vii+236 pages, 36 pls. 301 figs.

No. 249. Barus, Carl. The Interferometry of Reversed and Non-reversed Spectra.
- Part III: Displacement Interferometry by the Aid of Achromatic Fringes. Octavo, 100 pages, 71 figures.
- Part IV: Displacement Interferometry by the Aid of Achromatic Fringes. Octavo, 172 pages, 117 figures.

No. 256. Dickson, L. E. History of the Theory of Numbers. Vol. 1: Divisibility and Primality. Octavo, xii+486 pages.

No. 257. Whitman, Charles Otis. Posthumous Works of, Edited by Oscar Riddle. (Paper No. 28, Station for Experimental Evolution.)
- Vol. I: Orthogenetic Evolution in Pigeons. Quarto, x+194 pages, 88 plates, 36 figs.
- Vol. II: Inheritance, Fertility, and the Dominance of Sex and Color in Hybrids of Wild Species of Pigeons. Quarto, 224 pages, 39 plates, 11 figures.
- Vol. III: The Behavior of Pigeons. Edited by Harvey A. Carr. Quarto, xi+161 pages, 2 figures.

No. 259. Davenport, Charles B., and Mary F. Scudder. Naval Officers: Their Heredity and Development. (Paper No. 29, Station for Experimental Evolution.) Octavo, iv+236 pages, 60 charts.

No. 263 Tower, W. L. The Mechanism of Evolution in Leptinotarsa. Octavo, viii+340 pages, 19 plates, 156 figures.
- (Appendix). Breitenbecher, J. K. The Relation of Water to the Behavior of the Potato Beetle in a Desert. Octavo, pp. 341–384, 5 figures.

No. 265. Laughlin, Harry H. The Duration of the Several Mitotic Stages in the Dividing Root-tip Cells of the Common Onion. (Paper No. 30, Station for Experimental Evolution.) Octavo, 48 pages, 19 charts.

No. 270. Reichert, E. T. A Biochemic Basis for the Study of Problems of Taxonomy, Heredity, Evolution, etc., with especial reference to the Starches and the Tissues of Parent and Hybrid-Stocks, and to the Starches and the Hemoglobins of Varieties, Species, and Genera. Quarto.
- Part I: Summaries and Comparisons of the Properties of the Starches and of the Tissues of Parent-stocks and Hybrid-stocks. Applications of the Results of the Researches to the Germ-plasm, Variations, Fluctuations, Sports, Mutants, Species, Taxonomy, Heredity, etc. Notes and Conclusions. Pages xi+376, 34 plates, 820 charts.
- Part II: Special, General, and Comparative Laboratory Data of the Properties of the Starches and of the Tissues of Parent-stocks and Hybrid-stocks. Pages vii+458.

No. 278. Morgan, T. H., C. B. Bridges, and A. H. Sturtevant. Contributions to the Genetics of Drosophila melanogaster. Octavo, v+388 pages, 12 plates, 105 figures.
- I: The Origin of Gynandromorphs, by T. H. Morgan and C. B. Bridges.
- II: The Second Chromosome Group of Mutant Characters, by C. B. Bridges and T. H. Morgan.
- III: Inherited Linkage Variations in the Second Chromosome, by A. H. Sturtevant.
- IV: A Demonstration of Genes Modifying the Character "Notch," by T. H. Morgan

No. 279. Harris, J. Arthur, and Francis G. Benedict. A Biometric Study of Basal Metabolism in Man. Octavo, vi+266 pages, 30 diagrams.

No. 280. Benedict, F. G., W. R. Miles, Paul Roth, and H. Monmouth Smith. Human Vitality and Efficiency under Prolonged Restricted Diet. Octavo, xi+702 pages, 124 figures.

No. 281. Papers from the Department of Marine Biology of the Carnegie Institution of Washington. Vol. XIII. Octavo, 128 pages, 19 plates, 3 figures.
 Speidel, Carl Caskey. Gland Cells of Internal Secretion in the Spinal Cord of the Skates. 31 pages, 9 plates.
 Drew, Gilman A. The Structure and Ejaculation of the Spermatophores of *Octopu americana*. 14 pages, 3 plates.
 Clark, Hubert Lyman. The Distribution of the Littoral Echinoderms of the West Indies. 25 pages, 3 plates.
 Harvey, E. Newton. Further Studies on the Chemistry of Light Production in Luminous Organisms. 35 pages.
 Gudger, E. W. The Ovary of *Felichthys felis*, the Gaff-topsail Catfish: Its Structure and Function. 17 pages, 4 plates.

No. 283. Case, E. C. The Environment of Vertebrate Life in the Late Paleozoic in North America: A Paleogeographic Study. Quarto, VI+275 pages, 8 figures.

No. 285. Morgan, T. H. The Genetic and the Operative Evidence relating to Secondary Sexual Characters. Octavo, 108 pages, 5 plates.

No. 286. Weaver, John E. The Ecological Relations of Roots. Octavo, 128 pages, 33 plates, 58 figures.

No. 287. Spoehr, H. A. The Carbohydrate Economy of Cacti. Octavo, 79 pages, 2 figures.

No. 288. Castle W. E. Studies in Heredity in Rabbits, Rats, and Mice. Octavo, 56 pages, 3 plates, 5 figures.

No. 291. Contributions to the Geology and Paleontology of the West Indies. Octavo, 184 pages, 53 plates.
 Vaughan, Thomas Wayland. Introduction. 4 pages.
 Howe, Marshall A. Fossil Calcarous Algæ from the Leeward Islands. 11 pp., 6 pls.
 Cushman, Joseph A. Fossil Foraminifera from the West Indies. 11 pp., 15 pls.
 Canu, F., and R. S. Bassler. Fossil Bryozoa from the West Indies. 30 pp., 7 pls.
 Cooke, C. W. Fossil Mollusca from the Leeward Islands and Cuba. 54 pp., 16 pls.
 Rathbun, Mary J. Fossil Decapod Crustacea from the West Indies. 28 pp., 9 pls.

No. 295. Mohr, O. L., and Chr. Wriedt. A New Type of Hereditary Brachyphalangy in Man. Octavo, 64 pages, 7 pls, 4 figures.

Sales of Publications and Value of those on hand.

The following table shows the amounts received from subscriptions to the Index Medicus, from sales of Year Books, and from sales of all other publications for each year since the foundation of the Institution:

Table showing sales of publications.

Year.	Index Medicus.	Year Book.	Miscellaneous books.
1903.....	$2,256.91	$29.25	....
1904.....	2,370.47	52.85	$12.75
1905.....	2,562.76	44.75	431.44
1906.....	2,970.56	37.60	1,341.52
1907.....	3,676.71	56.50	2,292.89
1908.....	3,406.19	99.65	4,371.67
1909.....	4,821.85	73.01	6,287.21
1910.....	4,470.50	100.70	5,899.05
1911.....	4,440.21	85.50	6,366.55
1912.....	4,652.14	61.65	6,782.34
1913.....	4,992.02	75.95	7,140.69
1914.....	5,079.16	49.65	6,273.59
1915.....	5,010.21	47.60	5,239.98
1916.....	4,382.19	46.60	8,115.37
1917.....	4,616.21	51.55	7,253.59
1918.....	4,324.29	21.10	5,575.61
1919.....	4,267.95	93.30	8,476.33
Total...	68,300.33	1,027.21	81,860.58

At the end of the fiscal year there are on hand 99,207 volumes of miscellaneous publications and Year Books, having a sale value of $271,679.20; also 37,789 numbers of the Index Medicus, having a sale value of $20,593.25. The total value of publications on hand is therefore $292,272.45.

In connection with the above statement it is fitting to add that since the foundation of the Institution there have been distributed, chiefly by gifts to libraries and to authors, but to a noteworthy extent also by sales, a total of 190,404 volumes of publications of the Institution.

Growth and Extent of Institution's Publications.

The data furnished in the following table are of statistical interest in respect to the work of publication of the Institution. Four hundred and one volumes, embracing a total of 111,023 pages of printed matter, have thus far been issued by the Institution.

Table showing number of volumes, number of pages (octavo and quarto), and totals of pages of publications issued by the Institution for each year and for the eighteen years from 1902 to 1919.

Year.	Number of volumes issued.	Number of octavo pages	Number of quarto pages.	Total number of pages.
1902......	3	46	....	46
1903......	3	1,667	....	1,667
1904......	11	2,843	34	2,877
1905......	21	3,783	1,445	5,228
1906......	19	3,166	1,288	4,454
1907......	38	6,284	3,428	9,712
1908......	28	4,843	2,485	7,328
1909......	19	3,695	1,212	4,907
1910......	29	3,274	4,831	8,105
1911......	30	5,062	1,670	6,732
1912......	23	3,981	2,044	6,025
1913......	29	6,605	2,752	9,357
1914......	23	4,978	1,934	6,912
1915......	23	4,686	1,466	6,152
1916......	35	9,478	2,430	11,908
1917......	21	4,464	2,691	7,155
1918......	17	3,073	1,269	4,193
1919......	29	5,834	2,431	8,265
Total....	401	77,762	33,261	111,023

APPENDIX.

BIBLIOGRAPHY OF PUBLICATIONS RELATING TO WORK OF INVESTIGATORS, ASSOCIATES, AND COLLABORATORS.

Under this heading it is sought to include titles of all publications proceeding from work done under the auspices of the Carnegie Institution of Washington, exclusive of the regular publications. A list of the latter which have appeared during the year will be found in the President's Report (pp. 30-31).

ADAMS, L. H. Tables and curves for use in measuring temperatures with thermocouples. Bull. Amer. Inst. Min. Met. Eng., 2111-2124 (1919).

———, and E. D. WILLIAMSON. Some physical constants of mustard "gas." Jour. Wash. Acad. Sci., vol. 9, 30-35 (1919).

———, ———. Relation between birefringence and stress in various types of optical glass. (Papers on Optical Glass, No. 21.) Jour. Wash. Acad. Sci., vol. 9, 609-623 (1919).

———, ———, and JOHN JOHNSTON. The determination of the compressibility of solids at high pressures. Jour. Amer. Chem. Soc., vol. 41, 12-42 (1919).

———. See HALL, R. E.; WHITE, W. P.; WILLIAMSON, E. D.

ADAMS, WALTER S. The absorption spectrum of the Novæ. Proc. Nat. Acad. Sci., vol. 4, 355-360 (1918); Mt. Wilson Communications, No. 55.

———. The cause of Cepheid variation. Observatory, vol. 42, 167-168 (1919).

———, and ALFRED H. JOY. The motions in space of some stars of high radial velocity. Astrophys. Jour., vol. 49, 179-185 (1919); Mt. Wilson Contr., No. 163; Proc. Nat. Acad. Sci., vol. 5, 239-241 (1919).

———, ———. The orbits of three spectroscopic binaries. Astrophys. Jour., vol. 49, 186-195 (1919); Mt. Wilson Contr., No. 164.

———, ———. Spectroscopic notes. Pubs. A. S. P., vol. 30, 306-307 (1918).

———, ———. Fourteen spectroscopic binaries. Pubs. A. S. P., vol. 31, 40-42 (1919).

———, ———. The structure of the emission bands in the spectrum of Nova Aquilæ No. 3. Read at Pasadena meeting, A. S. P. (1919); Pubs. A. S. P., vol. 31, 182-184 (1919).

———, ———. Eighteen stars with spectra similar to those of the Cepheid variables. Read at Pasadena meeting, A. S. P. (1919); Pubs. A. S. P., vol. 31, 184-186 (1919).

———, and GUSTAF STRÖMBERG. On the use of the spectroscopic method for determining the parallaxes of the brighter stars. Proc. Nat. Acad. Sci., vol. 5, 228-232 (1919).

ALLEN, E. T., and E. G. ZIES. A contribution to the methods of glass analysis, with special reference to boric acid and the two oxides of arsenic. (Papers on Optical Glass, No. 5.) Jour. Amer. Ceram. Soc., vol. 1, 739-786 (1918).

———, ———. The condition of arsenic and its rôle in glass-making. (Papers on Optical Glass, No. 6.) Jour. Amer. Ceram. Soc., vol. 1, 787-790 (1918).

ANDERSEN, OLAF. A method for the determination of the volatile matter in oxides of lead. (Papers on Optical Glass, No. 18.) Jour. Amer. Ceram. Soc., vol. 2, 782-783 (1919).

———. The volatilization of lead oxide from lead silicate melts. (Papers on Optical Glass, No. 19.) Jour. Amer. Ceram. Soc., vol. 2, 784-789 (1919).

ANDERSON, JOHN A. The expedition of the Mount Wilson Observatory to the solar eclipse of June 8, 1918. Read at general meeting, Amer. Philos. Soc. (1919); Proc. Amer. Philos. Soc., vol. 58, 255-258 (1919).

———. The Stark effect for metals in the ultra violet. Read at Pasadena meeting, Amer. Phys. Soc. (1919).

AULT, J. P. The cruise of the *Carnegie* for 1919-1921. Terr. Mag., vol. 24, No. 3, 132 (Sept. 1919).

AVERY, B. T., Jr. See BLAKESLEE, A. F.

BABCOCK, E. B. See CARPENTER, T. M.

BABCOCK, HAROLD D. See ST. JOHN, CHARLES E.

BALDWIN, M. E. See SHERMAN, H. C.

BANTA, A. M. Sex and sex intergrades in Cladocera. Proc. Nat. Acad. Sci., vol. 4, 373-379 (Dec. 1918).

———. The extent of the occurrence of sex intergrades in Cladocera. Anat. Rec., vol. 15, 355-356 (Jan. 1919).

———. The results of selection with a Cladocera pure line (clone). Proc. Soc. Exper. Biol. and Med., vol. 16, 123-124 (May 1919).

BARNETT, S. J. A report on electromagnetic induction. Proc. Amer. Inst. Elec. Engin., vol. 38, No. 10, 1151-1169 (Oct. 1919).

BARUS, CARL. Non-reversed spectra of restricted coincidence. Proc. Nat. Acad. Sci., vol. 2, 614 (1916).

———. Path differences within which spectrum interferences are observable. Proc. Nat. Acad. Sci., vol. 2, 609 (1916).

———. Hygrometry in terms of the weight of a film of gelatine. Science, n. s., vol. 48, 374 (1918).

BARUS, CARL. Polarization of moving electrodes. Science, n. s., vol. 48, 253 (1918).
———. Interferences of vibrating systems. Proc. Nat. Acad. Sci., vol. 4, 328 (1918).
———. Gravitational attraction in connection with the rectangular interferometer. Proc. Nat. Acad. Sci., vol. 4, 338 (1918).
———. The rectangular interferometer with displacement fringes, in connection with the horizontal pendulum. Proc. Nat. Acad. Sci., vol. 5, 349 (1918).
———. Spectrum phenomena due to moving motes. Science, n. s., vol. 49, 72 (1919).
———. On Herschell's fringes. Science, n. s., vol. 49, 72 (1919).
———. An adjustment in relation to the Fresnel coefficient. Proc. Nat. Acad. Sci., vol. 5, 120 (1919).
Note on the self-adjusting interferometer in relation to the achromatic fringes. Proc. Nat. Acad. Sci., vol. 5, 53 (1919).
———. Interferometer contact lever experiments relating to the elastics of small bodies. Proc. Nat. Acad. Sci., vol. 5, 44 (1919).
———. Note on a contact lever using achromatic displacement fringes. Proc. Nat. Acad. Sci., vol. 5, 39 (1919).
———. An electrodynamometer using the vibration telescope. Proc. Nat. Acad. Sci., vol. 5 211 (1919).
BAUER, L. A. Results of magnetic observations during solar eclipse of June 8, 1918. (Abstract.) Jour. Wash. Acad. Sci., vol. 9, No. 1, 22 (Jan. 4, 1919).
———. Some interesting results of eclipse magnetic observations. (Abstract.) Phys. Rev., ser. 2, vol. 13, No. 2, 160–161 (Feb. 1919).
———. Proposed magnetic and allied observations during total solar eclipse of May 29, 1919. Terr. Mag., vol. 24, No. 1, 41–43 (Mar. 1919); Science, n. s., vol. 49, No. 1263, 260–261 (Mar. 14, 1919); Nature, vol. 103, No. 2577, 44–45 (Mar. 20, 1919); Pop. Astron., vol. 27, No. 4, 267 (Apr. 1919).
———. The field of a uniformly magnetized elliptic homœoid and applications. (Abstract.) Jour. Wash. Acad. Sci., vol. 9, No. 9, 267–269 (May 4, 1919).
———. Informal remarks regarding the work of the *Carnegie* and eclipse observations, May 29, 1919. Observatory, vol. 42, No. 539, 190–191 (May 1919).
———. Preliminary meeting of official Weather Bureau Directors at London, July 3–9, 1919. U. S. Dept. Agric., Monthly Weath. Rev., vol. 47, No. 7, 449 (July 1919).
———. International Union of Geodesy and Geophysics, at Brussels, July 12–28, 1919. U. S. Dept. Agric., Monthly Weath. Rev., vol. 47, No. 7, 449–450 (July 1919).
———. Terrestrial magnetism and electricity at the Brussels meetings, July 18–28, 1919. Terr. Mag., vol. 24, No. 3, 105–112 (Sept. 1919).
———. Some observations of the total solar eclipse of May 29, 1919, at Cape Palmas, Liberia. (Abstract.) Pop. Astron., vol. 27, No. 8, 524–526 (Oct. 1919).
———. Geophysics at the Brussels meetings, July 18–28, 1919. Science, n. s., vol. 50, No. 1296, 399–403 (Oct. 31, 1919).
———, H. W. FISK, and S. J. MAUCHLY. Results of magnetic and electric observations made during the solar eclipse of June 8, 1918—Continued. Terr. Mag., vol. 23, No. 4, 155–193 (Dec. 1918); vol. 24, Nos. 1 and 2, 1–28, 87–98 (Mar., June 1919).
BECK, CLAUDE S. The relative distribution of clasmatocytes in the various organs of the seven-day chick embryo. Anat. Rec., vol. 16, 143 (1919).
BENEDICT, CORNELIA GOLAY, and F. G. BENEDICT. The energy content of extra foods. Boston Med. and Surg. Jour., vol. 181, 415 (1919).
BENEDICT, FRANCIS G. Energy requirements of children from birth to puberty. Boston Med. and Surg. Jour., vol. 181, 107 (1919).
———, and ALICE JOHNSON. The energy loss of young women during the muscular activity of light household work. Proc. Amer. Phil. Soc., vol. 58, 89 (1919).
———, W. R. MILES, and ALICE JOHNSON. The temperature of the human skin. Proc. Nat. Acad. Sci., vol. 5, 218 (1919).
———. See BENEDICT, CORNELIA GOLAY; HARRIS, J. ARTHUR.
BENIOFF, HUGO. The interior of a star: A review. Pubs. A. S. P., vol. 31, 118–121 (1919).
BICHOWSKY, F. RUSSELL V. An unusual sulfur crystal. Jour. Wash. Acad. Sci., vol. 9, 126–131 (1919).
BJERKNES, J. On the structure of moving cyclones. Geofysiske Publikationer, No. 2, Kristiania (1919); Monthly Weather Rev. (Feb. 1919).
———. Weather Forecasting. Monthly Weather Rev. (Feb. 1919).
BLAKESLEE, A. F. A unifoliate mutation in the adzuki bean. Jour. Hered., vol. 10, 153–155. (Apr. 1919).
———. Sexual differentiation in the bread molds. Proc. Soc. Exper. Biol. Med., vol. 16, 131 (1919).
———, and B. T. AVERY. Mutations in the jimson weed. Jour. Hered., vol. 10, 111–120 (Mar. 1919).
BOSS, LEWIS, and H. RAYMOND. The vertex of stellar motions. Astron. Jour., No. 747 (Feb. 1919)

BOWEN, N. L. The identification of "stones" in glass. (Papers on Optical Glass, No. 4.) Jour. Amer. Ceram. Soc., vol. 1, 594–605 (1918).
———. Devitrification of glass. (Papers on Optical Glass, No. 9.) Jour. Amer. Ceram. Soc., vol. 2, 261–278 (1919).
BOYER, S. See RICHARDS, T. W.
BRIDGES, C. B. Specific modifiers of eosin eye color in *Drosophila melanogaster*. Jour. Exp. Zool., vol. 28, 337–384 (July 1919).
———. The genetics of purple eye color in *Drosophila*. Jour. Exper. Zool., vol. 28, 265–305 (May 1919).
———. Vermilion-deficiency. Jour. General Physiol., vol. 1, 645–656 (July 1919).
———, and O. L. MOHR. The inheritance of the mutant character "vortex." Genetics, vol. 4, 283–306 (May 1919).
———. See MORGAN, T. H.; STURTEVANT, A. H.
BURNETT, EDMUND C. 1919 in the light of 1788. Hist. Outlook, 171–174 (Apr. 1919).
CALDWELL, M. L. See SHERMAN, H. C.
CANNON, W. A. Some biological features of roots. Sci. Amer., vol. 109, 373 (1918).
CARPENTER, T. M., and E. B. BABCOCK. The concentration of alcohol in the tissues of hens after inhalation. Proc. Amer. Physiol. Soc., Amer. Jour. Physiol., vol. 49, 128 (1919).
———. See HENDRY, M. F.
CARTER, EDNA, and ARTHUR S. KING. A further study of metallic spectra produced in high vacua. Astrophys. Jour., vol. 49, 224–236 (1919); Mt. Wilson Contr., No. 166.
———, ———. Further observations on the production of metallic spectra by cathode luminescence. Read at Baltimore meeting, Amer. Phys. Soc. (1918); (Abstract) Phys. Rev., ser. 2, vol. 13, 152 (1919).
CASE, E. C. Permo-carboniferous time *vs.* Permo-carboniferous conditions. Jour. Geol., vol. 26, No. 6, 1 fig., 500–506 (Sept.–Oct. 1918).
CASH, JAMES R. Reaction of cells in tissue culture to ether. Anat. Rec., vol. 16, 146 (1919).
CASPARIS, H. R. Lymphatics of the omentum. Anat. Rec., vol. 15, 93–99 (1918).
CASTLE, W. E. Is the arrangement of the genes in the chromosome linear? Proc. Nat. Acad. Sci., vol. 5, 25–32 (Feb. 1919).
———. The linkage system of eight sex-linked characters of *Drosophila virilis* (data of Metz). Proc. Nat. Acad. Sci., vol. 5, 32–36 (Feb. 1919).
———. Piebald rats and the theory of genes. Proc. Nat. Acad. Sci., vol. 5, 126–130 (Apr. 1919).
———. Siamese, an albinistic color variation in cats. Amer. Nat., vol. 53, 265–268 (May 1919).
———. Piebald rats and selection—a correction. Amer. Nat., vol. 53, 370–375 (July 1919).
CLEMENTS, EDITH S. Flowers of mountain and plain. 2d ed. (1919).
CLEMENTS, FREDERIC E. Scope and significance of paleo-ecology. Bull. Geol. Soc., 371 (1918).
———. Plant geography. Enc. Americana (1919).
———, and EDITH S. CLEMENTS. Rocky mountain flowers. 3d ed. (1919).
COBLE, ARTHUR B. Theta modular group determined by point sets. Amer. Jour. Math., vol. 40, No. 4, 317–340 (Oct. 1918).
———. On the ten nodes of the rational sextic and of the Cayley symmetroid. Amer. Jour. Math., vol. 41, No. 4 (Oct. 1919).
CRAIG, W. M. See RICHARDS, T. W.
CULL, S. T. WALLIS. Spina bifida with associated disturbances in a human embryo 17 mm. long. Johns Hopkins Hosp. Bull., vol. 30, 181–183 (1919).
DAVENPORT, C. B. Report of the Surgeon General of the Army to the Secretary of War, 1918. 46–116; 164–226. Govt. Print. Office. (1918).
———. Brief studies in heredity (unsigned) in Eugenical News as follows: Vol. III, Thomas Woolner, 74; Henry Wisner, 81; Genseric, 82; Henry Adams, 89. Vol. IV, Benjamin Franklin, 1; Henry Fielding, 9; Ella Wheeler Wilcox, 17; Cyrus Pringle, 18; Thomas Jefferson, 29; John J. Pershing, 30; Alfred Harmsworth, 37; E. H. House, 54; William P. Jacobs, 54; Rose Cohen, 61.
———. The genetical factor in dental research. Jour. Dental Research, vol. 1, 9–11 (Mar. 1919).
———. Biology at Cold Spring Harbor. Bull. Brooklyn Inst. of Arts and Sci. (Apr. 1919) (Reprinted, 8 pp.).
———. Eugenics in relation to medicine. Oxford Loose Leaf Med. (1919).
———. Standard methods in research surveys. Proc. Nat. Conference of Charities and Correction, 4 pp. (1919).
———, and A. G. LOVE. A comparison of white and colored troops in respect to incidence of disease. Proc. Nat. Acad. Sci., vol. 5, 58–67 (Mar. 1919).
———, ———. Physical examination of the first million draft recruits: Methods and results. (Compiled under direction of the Surgeon General, War Department.) Office of the Surgeon General, Bull. No. 11, 1–521 (Mar. 1919).
———, ———. Immunity of city-bred recruits. Arch. Inter. Med., vol. 24, No. 2, 129–153 (Aug. 1919).
DAY, ARTHUR L. George Ferdinand Becker, 1847–1919. Amer. Jour. Sci., vol. 48, 242–245 (1919).
DOSDELL, LOUISE. Water requirement and adaptation in *Equisetum*. Plant World (1919).

DUESBERG, J. On the interstitial cells of the testicle of the *Didelphys*. Biol. Bull., vol. 35, 175–194 (1918).
———. On the present status of the chondriosome problem. Biol. Bull., vol. 36, 71–81 (1919).
ELLERMAN, FERDINAND. Solar research at the Mount Wilson Observatory. Pubs. A. S. P., vol. 31, 16–24 (1919).
———. Photographs of lightning. Camera Craft, vol. 25, 397 (1918).
———. See HALE, GEORGE E.; SEARES, FREDERICK H.
EMMES, L. E. See HENDRY, M. F.
FENNER, C. N. The technique of optical glass melting. (Papers on Optical Glass, No. 7.) Jour. Amer. Ceram. Soc., vol. 2, 102–145 (1919).
———. The use of optical pyrometers for control of optical glass furnaces. (Papers on Optical Glass, No. 13.) Bull. Amer. Inst. Min. Met. Eng., 1001–1011 (1919).
———. The relations between tridymite and cristobalite. Jour. Soc. Glass Technology, vol. 3, Trans., 116–125 (1919).
FERGUSON, J. B. The thermal dissociation of sulfur dioxide. Jour. Amer. Chem. Soc., vol. 41, 69–72 (1919).
———. Oxidation of lava by steam. Jour. Wash. Acad. Sci., vol. 9, 539–546 (1919).
———, and J. C. HOSTETTER. The rapid electrometric determination of iron in some optical glasses. (Papers on Optical Glass, No. 16.) Jour. Amer. Ceram. Soc., vol. 2, 608–621 (1919).
———, and P. D. V. MANNING. Equilibrium studies upon the Bucher process. Jour. Ind. Eng. Chem., vol. 11, 946–950 (1919).
———, and H. E. MERWIN. The ternary system CaO–MgO–SiO_2. (Preliminary report.) Proc. Nat. Acad. Sci., vol. 5, 16–18 (1919).
———, ———. The ternary system CaO–MgO–SiO_2. Amer. Jour. Sci., vol. 48, 81–123 (1919).
———, ———. Wollastonite and related solid solutions in the ternary system lime-magnesia-silica. Amer. Jour. Sci., vol. 48, 165–189 (1919).
———. See HOSTETTER, J. C.
FERRY, E. L. See OSBORNE, THOMAS B.
FISK, H. W. See BAUER, L. A.
FLEMING, J. A. Latest annual values of the magnetic elements at observatories. Terr. Mag., vol. 23, 191–193 (Dec. 1918).
———. Note on a string galvanometer for use on board ship. Terr. Mag., vol. 24, No. 1, 29–30, figs. (Mar. 1919).
GOODSPEED, T. H. See HALL, H. M.
HALE, GEORGE E. Industrial research and national welfare. Science, n. s., vol. 48, 505–507 (1918).
———. On the nature of sun-spots. (Abstract) Proc. Roy. Soc., A, vol. 95, 234–236 (1918).
———. The national engineering societies and the National Research Council. Jour. Amer. Soc. Mech. Eng., vol. 40, 825–829 (1918).
———. The National Research Council. Read at Baltimore meeting, A. A. A. S. (1918).
———. Cooperative research. Read before Royal Canadian Institute, Toronto (Apr. 9, 1919).
———. Science as a source of industrial progress. Address before members of the Legislature of the Province of Ontario, Toronto (Apr. 10, 1919).
———. The responsibilities of the scientist. Read at the Pasadena meeting, Pacific Division, A. A. A. S. (1919); Science, n. s., vol. 50, 143–146 (1919).
———. Stereoscopic photographs of the solar atmosphere. Read at Pasadena meeting, A. S. P. (1919).
———. The work of the amateur astronomer. Read at meeting of A. S. P., Berkeley (1919).
———, FERDINAND ELLERMAN, SETH B. NICHOLSON, and ALFRED H. JOY. The magnetic polarity of sun-spots. Astrophys. Jour., vol. 49, 153–178 (1919); Mt. Wilson Contr., No. 165.
HALL, H. M. Walnut pollen as a cause of hay fever. Science, n. s., 516 (1918).
———. Life zone indicators in California. Proc. Calif. Acad. Sci., 4th ser., vol. 9, 37 (1919).
———, with T. H. GOODSPEED. An emergency supply of rubber. Science, n. s., 452 (1918).
———, ———. A rubber survey of Western North America. Univ. Calif. Pub. Bot., vol. 7 (1919).
HALL, R. E., and L. H. ADAMS. Application of the thermionic amplifier to conductivity measurements. Jour. Amer. Chem. Soc., vol. 41, 1515–1525 (1919).
HARRIS, J. ARTHUR. The osmotic concentration of the tissue fluids of phanerogamic epiphytes. Amer. Jour. Bot., vol. 5, 490–506 (1918).
———. The transformation of the plant ovule into an ovary. Proc. Soc. Exp. Biol. and Med., vol. 16, 134–136 (1919).
———, and F. G. BENEDICT. A biometric study of human basal metabolism. Proc. Nat. Acad. Sci., vol. 4, 370–373 (1918).
———, ———. Biometric standards for energy requirements in human nutrition. Sci. Monthly, vol. 8, 385–402 (1919).
HARRIS, J. W. Influenza occurring in pregnant women: A statistical study of 1,350 cases. Jour. A. M. A., vol. 72, 978–980 (1919).

HARVEY, E. N. Reversibility of the photogenic reaction in Cypridina. Jour. Gen. Physiol., vol. 1, 135–145 (Nov. 1918).
———. Chemical nature of Cypridina Luciferin and Cypridina Luciferase. Jour. Gen. Physiol., vol. 1, 269–293 (Jan. 1919).
HAY, OLIVER P. On some proboscideans of the State of New York. Science, n. s., vol. 49, 377–379 (Apr. 1919).
———. Dr. Alĕx. Hrdlička and the Vero man. Science, n. s., vol. 48, 459–462 (Nov. 8, 1918).
———. Description of some mammalian and fish remains from Florida, of probably Pleistocene age. Proc. U. S. Nat. Mus., vol. 56, 103–112, with 3 pls. (July 31, 1919).
———. On the relative ages of certain Pleistocene deposits. Amer. Jour. Sci., vol. 47, 361–375 (May 1919).
HENDRY, M. F., T. M. CARPENTER, and L. E. EMMES. Gaseous exchange with unpracticed subjects and two respiration apparatus employing three breathing appliances. Boston Med. and Surg. Jour., vol. 181, 285, 334, and 368 (1919).
HOSTETTER, J. C. An apparatus for growing crystals under controlled conditions. Jour. Wash. Acad. Sci., vol. 9, 85–94 (1919).
———. The hydrochloric acid color method for determining iron. (Papers on Optical Glass, No. 17.) Jour. Amer. Chem. Soc., vol. 41, 1531–1543 (1919).
———. and H. S. ROBERTS. Electrometric titrations, with special reference to the determination of ferrous and ferric iron. Jour. Amer. Chem. Soc., vol. 41, 1337–1357 (1919).
———, ———, and J. B. FERGUSON. Volatilization of iron from optical glass pots by chlorine at high temperatures. (Papers on Optical Glass, No. 12.) Jour. Amer. Ceram. Soc., vol. 2, 356–372 (1919).
———. See FERGUSON, J. B.; MERWIN, H. E.
HUMASON, MILTON. The light curve of Nova Aquilæ No. 3. Pubs. A. S. P., vol. 31, 43–44 (1919).
JEAN, F. C. See WEAVER, J. E.
JOHNSON, ALICE. See BENEDICT, F. G.
JOHNSTON, JOHN. See ADAMS, L. H.
JOY, ALFRED H. The spectrum of RU Camelopardalis. Read at Pasadena meeting, A. S. P. (1919); Pubs. A. S. P., vol. 31, 180–181 (1919).
———. See ADAMS, WALTER S.; HALE, GEORGE E.
KEY, WILHELMINE E. Brief studies in eugenics (unsigned) in Eugenical News as follows: Vol. III, The modifiability of salient traits, 78; The field of genealogy, 79; A famous ancestress, 86; Eugenics and migration, 87; The making of a master of finance, 90. Vol. IV, Heredity of Theodore Roosevelt, 10; From generation to generation, 19; Well-known American families, 19; Coryell's ferry, 31; Colonial Amherst, 31; Bionomic family archives, 47; The Averell, Averill, Avery family, 67; Heredity ana racial differentiation, 67; Certain comeoverers, 57; Fertility and eminence, 60; Standardizing racial norms, 62; From carving knives to swords, 70; Measuring environmental influence, 70; Aptitude and the life work, 75.
KING, ARTHUR S. Discussion of some evidence on the origin of radiation in the tube-resistance furnace. Astrophys. Jour., vol. 49, 48–53 (1919); Mt. Wilson Contr., No. 162.
———. Absorption effects with the electric furnace as related to temperature classification. Read at Pasadena meeting, Amer. Phys. Soc. (1919).
———. The electric furnace spectra of metals in the infra-red. Read at Pasadena meeting, Amer. Phys. Soc. (1919).
———, and PAUL W. MERRILL. Recent observations of tube-arc spectra, especially in the infra-red. Read at Pasadena meeting, Amer. Phys. Soc. (1919).
———. See CARTER, EDNA.
LAUGHLIN, HARRY H The dynamics of cell-division. Proc. Soc. Exper. Biol. and Med., vol. 15, No. 8 (1918).
———. Population schedule for the census of 1920. Jour. Hered., vol. 10, No. 5 (May 1919).
———. The relations of eugenics to other sciences. Eugenics Review (London), vol. 11, No. 2 (July 1919).
———. The relations between the number of chromosomes of a species and the rate of elimination of mongrel blood by the pure-sire method. Proc. Soc. Exper. Biol. and Med., vol. 16, 132–134 (1919).
———. Brief reviews and studies (unsigned) in Eugenical News, among them the following: Vol. III, Four motives for human pedigree study, 54; The Nevada sterilization law, 62; The intimate life of Alexander Hamilton, 65; A fertile field for eugenics, 72; Future immigration, 91. Vol. IV, Alumni roster of the eugenics course, 21; The Eugenics Research Association, 32; Training course for field workers, 40; The position of field workers, 41; Life of Stonewall Jackson, 46; Life of Nathan B. Forrest, 47; A century of negro migration, 50.
LELAND, WALDO G. Reconstruction in the United States. Quart. Rev., 177–193 (July 1919).
LEWIS, MARGARET R. The formation of fat droplets in the cells of tissue cultures. Science, n. s., vol. 48, 398 (1918).
———. The development of the cross-striated myofibril in the heart muscle of the chick embryo. Anat. Rec., vol. 16, 154 (1919).

LEWIS, MARGARET R. The development of cross striations in the heart-muscle of the chick embryo. Johns Hopkins Hosp. Bull., vol. 30, 81–90 (1919).

LEWIS, WARREN H. Degeneration granules and vacuoles in the fibroblasts of chick embryos cultivated *in vitro*. Johns Hopkins Hosp. Bull., vol. 30, 81–90 (1919).

———. The centriole and centrosphere in degenerating fibroblasts of tissue cultures. Anat. Rec., vol. 16, 155 (1919).

LITTLE, C. C. A note on the fate of individuals homozygous for certain color factors in mice. Amer. Nat., vol. 53, 185–187 (Mar. 1919).

———. Some factors influencing the human sex-ratio. Proc. Soc. for Exper. Biol. and Med., vol. 16, 127–130 (1919).

LONG, FRANCES. A quantitative determination of photosynthetic efficiency in plants. Phys. Res., vol. 2, 277 (1919).

LOVE, A. G. See DAVENPORT, C. B.

MACDOUGAL, D. T. Growth in organisms. Science, n. s., vol. 49, 599 (1919).

———, H. M. RICHARDS, and H. A. SPOEHR. The basis of succulence in plants. Bot. Gaz., vol. 67, 405 (1919).

———, and H. A. SPOEHR. The solution and fixation accompanying swelling and drying of biocolloids and plant tissues. Plant World, vol. 22, 129–138 (June 1919).

———, ———. The effect of organic acids and their amino-compounds on the hydration of agar and on a biocolloid. Proc. Soc. Exper. Biol. and Med., vol. 16, 33 (1918).

———, ———. The origination of xerophytism. Plant World, vol. 21, 245 (1918).

MACDOWELL, E. C. The influence of parental alcoholism upon habit formation in albino rats. Proc. Soc. Exper. Biol. and Med., vol. 16, 125–126 (1919).

MALLORY, WILLIAM G. The distribution of energy in the spectrum of erbium oxide. Phys. Rev. (2), vol. 14, 54 (1919).

MANNING, P. D. V. See FERGUSON, J. B.

MAUCHLY, S. J. Some results of atmospheric-electric observations made during the solar eclipse of June 8, 1918. (Abstract.) Jour. Wash. Acad. Sci., vol. 9, No. 9, 269–270 (May 4, 1919).

———. Note on a possible explanation of the "electric tide" observed at Jersey. Terr. Mag., vol. 24, No. 2, 99 (June 1919).

See BAUER, L. A.

MAYOR, A. G. Growth rate of Samoan coral reefs. Proc. Nat. Acad. Sci., vol. 4, 390–393 (Nov. 1918).

———. Detecting ocean currents by observing their hydrogen-ion concentration. Proc. Amer. Philos. Soc., vol. 58, 150–160 (1919).

MCINTOSH, WILLIAM A. Histological study of fat contained in the mucosa of the alimentary tract of moderately starved cats. Amer. Jour. Phys., vol. 46, 570–583 (1918).

MENDEL, LAFAYETTE B. Food factors in gastro-enterology. Amer. Jour. Med. Sci.

———. See OSBORNE, THOMAS B.

MERRILL, PAUL W. The spectra of krypton and xenon in the infra-red. Read at Pasadena meeting, Amer. Phys. Soc. (1919).

———. A study of the relative intensities of spectrum lines in different regions of the arc as compared with their behavior in other sources. Read at Pasadena meeting, Amer. Phys. Soc. (1919).

See KING, ARTHUR S.

MERWIN, H. E. Ammonium picrate and potassium trithionate: Optical dispersion and anomalous crystal angles. Jour. Wash. Acad. Sci., vol. 9, 429–431 (1919).

———, and J. C. HOSTETTER. Hematite and rutile formed by the action of chlorine at high temperatures. Amer. Mineralogist, vol. 4 126–127 (1919).

———. See FERGUSON, J. B.; POSNJAK, EUGEN.

METZ, C. W. *Anopheles crucians:* Habits of larvæ and adults. Pub. Health Rep., 2156–2269 (Dec. 6, 1919) (Reprint No. 495, 1918).

———. Some aspects of malaria control through mosquito eradication. Pub. Health Rep. vol. 34, 167–183 (Jan. 31, 1919) (Reprint No. 500).

———. *Anopheles crucians* as an agent in malaria transmission. Pub. Health Rep., vol. 34, 1355–1360 (June 20, 1919).

MEYER, ARTHUR W. Hydatiform degeneration in tubal pregnancy. Surg., Gyn., and Obst., vol. 28 (1919).

———. On the nature, occurrence, and identity of the plasma cells of Hofbauer. Jour. Morph., vol. 32, 327–347 (1919).

———. The occurrence of superfetation. Jour. A. M. A., vol. 72, 769–774 (1919).

———. Sidelights on abnormal conceptuses. Anat. Rec., vol. 16, 169 (1919).

———. Uterine, tubal, and ovarian lysis and resorption of conceptuses. Biol. Bull., vol. 36, 283–308 (1919).

———, and H. M. N. WYNNE. Some aspects of ovarian pregnancy, with report of a case. Johns Hopkins Hosp. Bull., vol. 30, 92–98 (1919).

MILES, W. R. The sex expression of men living on a lowered nutritional level. Jour. Mental and Nervous Disease, vol. 49, 208 (1919).

———. See BENEDICT, F. G.

Miller, Charles H. Nitrate cellulose as a substitute for celloidin. Trans. Amer. Micr. Soc., vol. 37 (1919).
Mogensen, Anne. See Weaver, J. E.
Mohr, O. L., and A. H. Sturtevant. A semi-lethal in *Drosophila funebris* that causes an excess of males. Proc. Soc. Exper. Biol. and Med., vol. 16, 95, 96 (1919).
———. See Bridges, C. B.
Morey, G. W. An improved method of optical glass manufacture. (Papers on Optical Glass, No. 8.) Jour. Amer. Ceram. Soc., vol. 2, 146–150 (1919).
Morgan, T. H., and C. B. Rridges. The inheritance of a fluctuating character. Jour. General Physiol., vol. 1, 639–643 (July 1919).
———, ———. The construction of chromosome maps. Proc. Soc. Exper. Biol. and Med., vol. 16, 96, 97 (1919).
———. See Sturtevant, A. H.
Moulton, F. R. Numerical integration of differential equations. Jour. U. S. Artillery, vol. 51, No. 1, 40-55 (July 1919).
Nichols, E L., and Horace L. Howes. Fluorescence and absorption of the uranyl sulphates. Phys. Rev. (2), vol. 14, 293 (1919).
———, ———, and Frances G. Wick. Fluorescence and absorption of the uranyl acetates. Phys. Rev. (2), vol. 14, 201 (1919).
Nicholson, Seth B. The relation between the size of a sun-spot and the strength of its magnetic field. Read at Pasadena meeting, A. S. P. (1919).
———. The variation in sun-spot activity during the present cycle. Read at Pasadena meeting, A. S. P. (1919); Pubs. A. S. P., vol. 31, 223–226 (1919).
———. See Hale, George E.
Norris, Edgar H. The early morphogenesis of the human thyroid gland. Amer. Jour. Anat., vol. 24 (1918).
Osborne, Thomas B., and Lafayette B. Mendel. Vitamines in green leaves. Proc. Soc. Biol. and Med. (Nov. 20, 1918).
———, ———. The vitamines in green foods. Jour. Biol. Chem. (Jan. 1919).
———, ———. The nutritive value of the wheat kernel and its milling products. Jour. Biol. Chem. (Apr. 1919).
———, ———, The "fat-soluble vitamine" of green foods. Proc. Amer. Soc. Biol. Chem.; Jour. Biol. Chem.
———, ———. The extraction of "fat-soluble vitamine" from green foods. Proc. Soc. Exp. Biol. and Med. (Mar. 19, 1919).
———, ———. The nutritive value of yeast protein. Jour. Biol. Chem. (June 1919); Proc. Amer. Physiol. Soc.; Amer. Jour. Physiol.
———, ———, and E. L. Ferry. A method of expressing numerically the growth-promoting value of proteins. Jour. Biol. Chem. (Feb. 1919).
Palitzsch, S. See Richards, T. W.
Paullin, Charles O. Documents relating to the battle of Lake Erie. Rowfant Club, Cleveland, Ohio (1919).
Pease, Francis G. Photographs of nebulæ. Read at Pasadena meeting, A. S. P. (1919).
Phillips, V. See Sherman, H. C.
Pool, R. J. See Weaver, J. E.
Posnjak, Eugen, and H. E. Merwin. Note on the Bucher cyanide process for the fixation of nitrogen. Jour. Wash. Acad. Sci., vol. 9, 28–30 (1919).
———, ———. The hydrated ferric oxides. Amer. Jour. Sci., vol. 47, 311–348 (1919).
Richards, H. M. See MacDougal, D. T.
Richards, T. W. The problem of radioactive lead. Science, n. s., vol. 49, 1–11 (Jan. 1919).
———, and S. Boyer. The purification of gallium by electrolysis and the compressibility and density of gallium. Jour. Amer. Chem. Soc., vol. 41, 133–134 (Feb. 1919); Proc. Nat. Acad. Sci.
———, W. M. Craig, and J. Sameshima. The purification by sublimation and the analysis of gallium chloride. Jour. Amer. Chem. Soc., vol. 41, 131–132 (Feb. 1919); Proc. Nat. Acad. Sci.
———, and S. Palitzsch. Compressibility of aqueous solutions, especially of urethane, and the polymerization of water. Jour. Amer. Chem. Soc., vol. 41, 59–69 (Jan. 1919); Compt. Rend. of Carlsberg Laboratorium.
———, and W. C. Schumb. The refractive index and the solubilities of the nitrates of lead isotopes. Jour. Amer. Chem. Soc., vol. 40, 1403–1409 (Sept. 1918).
Richmond, Myrtle L. See Shapley, Harlow.
Roberts, H. S. Electrical apparatus for use in electrometric titration. Jour. Amer. Chem. Soc., vol. 41, 1358–1362 (1919).
———. The cooling of optical glass melts. (Papers on Optical Glass, No. 14.) Jour. Amer. Ceram, Soc., vol. 2, 543–563 (1919).
———. See Hostetter, J. C.; Williamson, E. D.

RODÈS, LUIS. On the relation of the Doppler effect to Kirchoff's law. Pubs. A. S. P., vol. 31, 91–102 (1919).
———. On the relative intensity of the absorption lines in a spectroscopic binary. Pubs. A. S. P., vol. 31, 110–112 (1919).
SAMESHIMA, J. See RICHARDS, T. W.
SANFORD, ROSCOE F. Two Novæ in the Andromeda nebula. Pubs. A. S. P., vol. 30, 341 (1918).
———. Spectrum of the crab nebula. Pubs. A. S. P., vol. 31, 108–109 (1919).
———. Two new Novæ in the Andromeda nebula. Pubs. A. S. P., vol. 31, 109–110 (1919).
———. Orbit of the spectroscopic binary *p* Velorum. Lick Obs. Bull., vol. 9, 181–183 (1918).
———. See VAN MAANEN, ADRIAAN.
SARTON, G. The history of science. Science, n. s., vol. 49, 497 (1919).
———. Isis. N. Y. Eve. Post (Feb. 22, 1919).
———. The publication of Isis. Science, n. s., vol. 49, 170–171 (1919).
———. Une Encyclopédie Léonardesque. Raccolta Vinciana, vol. 10, 235–242 (1919).
———. Le Nouvel Humanisme. Scientia, vol. 23, 161–175 (1918).
———. The teaching of the history of science. Sci. Month., vol. 7, 193–211 (1918).
———. The message of Leonardo. His relation to the birth of modern science. Scribner's Mag., vol. 65, 531–540 (May 1919).
SCHULTZ, A. H. Changes in fetuses due to formalin preservation. Amer. Jour. Phys. Anthropol., vol. 2, 35–41 (1919).
———. Observations on the canalis basilaris chordæ. Anat. Rec., vol. 15, 225–229 (1918).
SCHUMB, W. C. See RICHARDS, T. W.
SEARES, FREDERICK H. Relation of color to intrinsic luminosity in stars of the same spectral type. Proc. Nat. Acad. Sci., vol. 5, 232–238 (1919).
———, and HARLOW SHAPLEY. The variation in light and color of RS Boötis. Astrophys. Jour., vol. 48, 214–240 (1918); Mt. Wilson Contr., No. 159.
———, ADRIAAN VAN MAANEN, and FERDINAND ELLERMAN. Deviations of the sun's general magnetic field from that of a uniformly magnetized sphere. Proc. Nat. Acad. Sci., vol. 5, 242–246 (1919).
SENIOR, H. D. The development of the arteries of the human lower extremity. Amer. Jour. Anat., vol. 25, 55–95 (1919).
SHAPLEY, HARLOW. Studies of magnitudes in star clusters: IX. The distances and distribution of seventy open clusters. Proc. Nat. Acad. Sci., vol. 5, 344–351 (1919).
———. The age of the earth. Pubs. A. S. P., vol. 30, 283–298 (1918); Sci. Amer., vol. 87, 34–35, 42–43 (1919).
———. On radiation and the age of the stars. Read at Pasadena meeting, A. S. P. (1919); Pubs. A. S. P., vol. 31, 178–180 (1919).
———. Nineteen new variable stars. Pubs. A. S. P., vol. 31, 226 (1919).
———. The "new star" in Serpens, 7. 1917. Pubs. A. S. P., vol. 31, 226–230 (1919).
———. Globular clusters, Cepheid variables, and radiation. Nature, vol. 103, 25–27 (1919).
———. The age of the stars. Nature, vol. 103, 284 (1919).
———. Note on the explanation of the absence of globular clusters from the midgalactic regions. Observatory, vol. 42, 82–84 (1919).
———. Darkening at the limb of a pulsating variable star. Observatory, vol. 42, 168–170 (1919).
———. Star clusters. Read at general meeting, Amer. Philos. Soc. (1919).
———, and MYRTLE L. RICHMOND. Note relative to the local cluster. Read at Pasadena meeting, A. S. P. (1919); (Abstract) Pubs. A. S. P., vol. 31, 186 (1919).
———, and MARTHA B. SHAPLEY. Studies based on the colors and magnitudes in stellar clusters: Thirteenth paper. The galactic planes in 41 globular clusters. Astrophys. Jour., vol. 50, 42–49 (1919); Mt. Wilson Contr., No. 160.
———, ———. Studies based on the colors and magnitudes in stellar clusters: Fourteenth paper. Further remarks on the structure of the galactic system. Astrophys. Jour., vol. 50, 107–140 (1919); Mt. Wilson Contr., No. 161.
See SEARES, FREDERICK H.
SHAPLEY, MARTHA B. The light curve and orbital elements of the eclipsing binary Y Leonis. Pubs. A. S. P., vol. 30, 343–346 (1918).
———. See SHAPLEY, HARLOW.
SHEPHERD, E. S. The composition of the gases of Kilauea. Bull. Hawaiian Volcano Obs., vol. 7, 94–97 (1919).
SHERMAN, H. C. Fundamental requirements of human nutrition. Proc. Inst. Med. of Chicago, vol. 2, 33 (1918).
———. Permanent gains from the food conservation movement. Columbia Univ. Quart., vol. 21, 1 (Jan. 1919).
———, A. W. THOMAS, and M. E. BALDWIN. Influence of hydrogen-ion concentration upon enzymic activity of three typical amylases. Jour. Amer. Chem. Soc., vol. 41, 231 (Feb. 1919).

SHERMAN, H. C., F. WALKER, and M. L. CALDWELL. Action of enzymes upon starches of different origin. Jour. Amer. Chem. Soc., vol. 41, 1123 (July 1919).
———, J. C. WINTERS, and V. PHILLIPS. Efficiency of oat protein in adult human nutrition. Jour. Biol. Chem., 39, 53–62 (Aug. 1919).
SHREVE, EDITH B. A thermo-electrical method for the determination of leaf temperature. Plant World, vol. 22, 118–122 (1918).
———. Investigations of the absorption of water by gelatine. Jour. Franklin Inst., vol. 187, 319–337 (1919).
———. The rôle of temperature in the determination of the transpiring power of leaves by hygrometric paper. Plant World, vol. 22, 100–104 (1919).
SHREVE, FORREST. The establishment of desert perennials. Jour. of Ecol., vol. 5, 210–216 (1917).
———. The vegetation of the Pinaleno Mountains of southern Arizona. Plant World, vol. 22, (1919).
SPOEHR, H. A. The development of conceptions of photosynthesis since Ingen-Housz. Sci. Monthly, vol. 9, 32–47 (1919).
———. See MACDOUGAL, D. T.
ST. JOHN, CHARLES E. The present condition of the problem of solar rotation. Pubs. A. S. P., vol. 30, 319–325 (1918).
———, and HAROLD D. BABCOCK. Are the wave-lengths of the atmospheric absorption lines variable? Read at Pasadena meeting, A. S. P. (1919); (Abstract) Pubs. A. S. P., vol. 31, 178 (1919).
———, and LOUISE W. WARE. On the source of discordant values for solar rotation. Read at Pasadena meeting, A. S. P. (1919); (Abstract) Pubs. A. S. P., vol. 31, 186 (1919).
STOCK, LEO F. An early Jesuit work on the writing and judging of history. Catholic Hist. Rev., 66–70 (Apr. 1919).
———. Summary of war legislation of the 65th Congress. Hist. Outlook, 401–419 (Oct. 1919).
STREETER, G. L. Factors involved in the formation of the filum terminale. Amer. Jour. Anat., vol. 25, 1–11 (1919).
———. A very young monozygotic twin. Anat. Rec., vol. 16, 164 (1919).
STRÖMBERG, GUSTAF. See ADAMS, WALTER S.
STURTEVANT, A. H., C. B. BRIDGES, and T. H. MORGAN. The spatial relations of genes. Proc. Nat. Acad. Sci., vol. 5, 168–173 (May 1919).
TAKAMINE, TOSHIO. The Stark effect for metals. Astrophys. Jour., vol. 50, 23–41 (1919); Mt. Wilson Contr., No. 169.
THOMAS, A. W. See SHERMAN, H. C.
VANCE, HARRY W. The structure of the clasmatocyte. Anat. Rec., vol. 16, 166 (1919).
VAN DER STRICHT, O. The development of the pillar cells, tunnel space, and Nuel's spaces in the organ of Corti. Jour. Compar. Neurol., vol. 30, 283–314 (1919).
VAN MAANEN, ADRIAAN. Investigations on proper motion: First paper. The motions of 85 stars in the neighborhood of Atlas and Pleione. Mt. Wilson Contr., No. 167.
———. Investigations on proper motion: Second paper. The motions of 162 stars in the neighborhood of the Orion nebula. Mt. Wilson Contr., No. 168.
———. The distances of six planetary nebulæ. Proc. Nat. Acad. Sci., vol. 4, 394–396 (1918); Mt. Wilson Communications, No. 56.
———. Evidence of stream motion afforded by the faint stars near the Orion nebula. Proc. Nat. Acad. Sci., vol. 5, 225–228 (1919).
———. The parallax of the Andromeda nebula. Pubs. A. S. P., vol. 30, 307 (1918).
———. The parallax of B. D. +36° 3956. Pubs. A. S. P., vol. 30, 308 (1918).
———. Parallax notes. Pubs. A. S. P., vol. 30, 342–343 (1918).
———. A very faint star of spectral type F. Pubs. A. S. P., vol. 31, 42–43 (1919).
———. The masses and absolute magnitudes of visual binaries. Read at Pasadena meeting, A. S. P. (1919); Pubs. A. S. P., vol. 31, 231–233 (1919).
———. Stellar parallaxes derived from photographs made with the 60-inch reflector of the Mount Wilson Observatory. Astron. Jour., vol. 32, 86–88 (1919).
———. J. C. Kapteyn. California Southland, No. 5 (1919).
———, and ROSCOE F. SANFORD. Preliminary parallax of Nova Aquilæ No. 3. Read at Pasadena meeting, A. S. P. (1919); Pubs. A. S. P., vol. 31, 234 (1919).
———. See SEARES, FREDERICK, H.
VAUGHAN, T. W. Correlation of the Tertiary formations of the southeastern United States, Central America, and the West Indies. Jour. Wash. Acad. Sci., vol. 8, 268-278 (May 1918).
———. Geologic history of Central America and the West Indies during Cenozoic time. Bull. Geol. Soc. Amer., vol. 29, 615–630 (1919).
———. Fossil corals from Central America, Cuba, and Porto Rico, with an account of the American Tertiary, Pleistocene, and Recent coral reefs. U. S. Nat. Mus. Bull. 103, 189–523, pls. 68–152, 22 text-figs. (1919).
———. The biologic character and geologic correlation of the sedimentary formations of Panama, in their relation to the geologic history of Central America and the West Indies. U. S. Nat. Mus. Bull. 103, 547–612 (1919).

VAUGHAN, T. W. Corals and the formation of coral reefs. Smithsonian Inst. Ann. Rept., 1917, 189–238, 37 pls., 16 text-figs. (1919).
WALKER, F. See SHERMAN, H. C.
WALLIS, W. F. The magnetic storm of August 11–12 as observed at the Watheroo Magnetic Observatory. Terr. Mag., vol. 24, No. 3, 135 (Sept. 1919).
WARE, LOUISE W. See ST. JOHN, CHARLES E.
WATSON, E. M. The development of the human verumontanum. Johns Hopkins Hosp. Bull., vol. 29, 241–246 (1918).
WEAVER, J. E. The quadrat method in teaching ecology. Plant World (1918).
———, with ANNE MOGENSON. Autumn and Winter transpiration rates of broad leaves and conifers. Bot. Gaz. (1919).
———, with R. J. POOL, and F. C. JEAN. Further studies in the Ecotone between Prairie and Forest. Univ. Nebr. Studies (1919).
WHITE, W. P. Silicate specific heats: Second series. Amer. Jour. Sci., vol. 47, 1–43 (1919).
———. Specific heat determination at higher temperatures. Amer. Jour. Sci., vol. 47, 44–59 (1919).
———. Potentiometers for thermoelement work. Bull. Amer. Inst. Min. Met. Eng., 1763–1772 (1919).
———, and L. H. ADAMS. A furnace temperature regulator. Phys. Rev., vol. 14, 44–48 (1919).
WIELAND, G. R. The needs of paleobotany. Science, n. s., vol. 50, 68–69 (July 18, 1919).
———. Classification of the Cycadophyta. Amer. Jour. Sci., vol. 47, 391–406 (June 1919).
———. A study of some American fossil cycads: Part VIII. Notes on young floral structures. Amer. Jour. Sci., vol. 46, 645-650 (Nov. 1918).
WILLIAMSON, E. D. Strains due to temperature gradients, with special reference to optical glass. (Papers on Optical Glass, No. 10.) Jour. Wash. Acad. Sci., vol. 9, 209–217 (1919).
———, and L. H. ADAMS. Temperature distribution in solids during heating or cooling. (Papers on Optical Glass, No. 11.) Phys. Rev., vol. 14, 99–114 (1919).
———, and H. S. ROBERTS. Thermocouple installation in annealing kilns for optical glass. (Papers on Optical Glass, No. 15.) Bull. Amer. Inst. Min. Met. Eng., 1445–1453 (1919.)
———. See ADAMS, L. H.
WINTERS, J. C. See SHERMAN, H. C.
WRIGHT, FRED EUGENE. War-time development of the optical industry. (Papers on Optical Glass, No. 20.) Jour. Optical Soc. Amer., vol. 2, 1–7 (1919).
———. Sights and fire-control apparatus. Chapter 6, pp. 135–147, of "America's Munitions, 1917–1918," Report of the Director of Munitions, War Department, Washington, 1919.
WYCKOFF, RALPH W. G. The nature of the forces between atoms in solids. Jour. Wash. Acad. Sci., vol. 9, 565-592 (1919).
WYNNE, H. M. N. See MEYER, A. W.
ZIES, E. G. See ALLEN, E. T.

REPORT OF THE EXECUTIVE COMMITTEE.

REPORT OF THE EXECUTIVE COMMITTEE.

To the Trustees of the Carnegie Institution of Washington:

GENTLEMEN: Article V, Section 3, of the By-Laws provides that the Executive Committee shall submit, at the annual meeting of the Board of Trustees, a report for publication; and Article VI, Section 3, provides that the Executive Committee shall also submit, at the same time, a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year. In accordance with these provisions, the Executive Committee herewith respectfully submits its report for the fiscal year ending Oct. 31, 1919.

During this year the Executive Committee held nine meetings, printed reports of which have been mailed to each Trustee.

Upon the adjournment of the meeting of the Board of Trustees of December 13, 1918, the members of the Executive Committee met and organized by the election of Mr. Walcott as Chairman for 1919, and by voting that the Assistant Secretary of the Institution act as Secretary of the Committee for the same period.

The President's report gives in detail the results of the work of the Institution for the fiscal year 1918–1919, together with itemized financial statements for the same period and a summary of receipts and expenditures of the Institution to date. The President also submits a report and an outline of suggested appropriations for the year 1920. The Executive Committee hereby approves the report and the recommendations of the President as the report and recommendations of the Committee.

The Board of Trustees at its meeting of December 13, 1918, instructed the Executive Committee to appoint Messrs. Arthur Young & Co., of Chicago and New York, to audit the accounts of the Institution for the fiscal year ending October 31, 1919. The report of the auditor, including a balance sheet showing the assets and liabilities of the Institution on October 31, 1919, is herewith submitted as a part of the report of the Executive Committee.

There is also submitted a statement of receipts and disbursements since the organization of the Institution on January 28, 1902.

No vacancies exist in the membership of the Board of Trustees or of any of its standing committees.

CHARLES D. WALCOTT, *Chairman.*
CLEVELAND H. DODGE.
WM. BARCLAY PARSONS.
STEWART PATON,
HENRY S. PRITCHETT.
ELIHU ROOT.
HENRY WHITE.
ROBERT S. WOODWARD.

November 14, 1919.

AGGREGATE RECEIPTS AND DISBURSEMENTS FROM ORGANIZATION, JANUARY 28, 1902, TO OCTOBER 31, 1919.

RECEIPTS.

Interest:		
Endowment	*$14,573,956.49	
Reserve Fund	484,012.76	
Insurance Fund	52,220.23	
Colburn Fund	15,269 95	
Pension Fund	2,349.67	
		$15,127,809.10
Colburn Fund		52,015.74
Sales of Publications:		
Index Medicus	68,300.33	
Year Book	1,027.21	
Miscellaneous	81,860 58	
		151,188.12
Revertments:		
Grants	163,049 63	
Administration	10,381 53	
Unappropriated balance	10,381 56	
		183,812.72
Miscellaneous:		
Carnegie Corporation of N. Y	580,000.00	
Insurance	5,142.01	
Sale of paper	5,779.69	
		590,921.70
Redemption and Sale of Bonds		1,395,609.37
		17,501,356.75

DISBURSEMENTS.

Investment:		
Securities	$4,507,395.21	
Collection charges	5,307.50	
Administration Building and Site	309,915.69	
		$4,822,618.40
Pension Fund		5,688.94
Insurance		3,270.94
Grants:		
Large	8,726,679.67	
Minor	1,827,123.88	
		10,553,803.55
Publication		757,376.68
National Research Council		130,000.00
Administration:		
Trustees	43,720.39	
Executive Committee	28,849.22	
Honorariums	17,319.81	
Salaries	473,303.00	
Shipping publications	47,095.86	
Rents, surety, telephone	31,939.53	
Equipment	15,714.20	
Postage, express	22,401.48	
Printing	†52,968.14	
Office expenses	26,277.82	
Building and grounds:		
Supplies, janitor	22,751.58	
Fuel, light, water	9,721.87	
Organization (1902)	1,825.52	
Plans and option	5,166.46	
Seal (1903)	555.60	
Miscellaneous	70.23	
		799,680.71
Refund:		
Publication	20.25	
Index Medicus	86.99	
		107.24
		17,072,546.46
Cash in banks		428,810.29
		17,501,356.75

*Including interest from Income and Building Fund bonds. †Including Year Books.

REPORT OF AUDITORS.

ARTHUR YOUNG & COMPANY

ACCOUNTANTS AND AUDITORS, 71 BROADWAY (EMPIRE BUILDING).

Auditors' Certificate.

Hon. ELIHU ROOT,
Chairman of the Board of Trustees,
Carnegie Institution of Washington,
Washington, D. C.

SIR: In accordance with instructions we have audited the books and records of THE CARNEGIE INSTITUTION OF WASHINGTON for the year ended October 31, 1919.

Income from investments and other sources has been duly accounted for and all disbursements were evidenced by properly approved vouchers. The bank and cash balances have been verified. We examined and agreed the securities belonging to the various funds as detailed in Schedule 1. The details of the expenditure of the Departments of Research have been audited by the Bursar of the Institution and were not examined by us.

We certify that the accompanying Balance Sheet and the statements attached thereto correctly set forth the financial condition of the Institution at October 31, 1919.

Yours truly,

ARTHUR YOUNG & CO.

NEW YORK, *November 20, 1919.*

Exhibit A.—Certified Balance Sheet at October 31, 1919

ASSETS.

Investments of the Endowment and Other Funds:			
Bonds (Schedule 1)		$25,527,284.99	
Cash on Deposit		45,418.73	
			$25,572,703.72
Assets of the Plant Capital:			
Real Estate and Equipment (Schedule 2)		2,870,087.77	
Inventories—			
Publications, at cost	$292,272.45		
Paper Stock	21,451.25		
		313,723.70	
Accounts Receivable		2,686 91	
			3,186,498.38
Assets Belonging to Income:			
Cash in Banks for current purposes		383,391.56	
Petty Cash and Stamps		300.00	
			383,691.56
			29,142,893.66

LIABILITIES

Endowment and Other Funds:			
Carnegie Endowment Fund		$22,120,000.00	
Harriman Fund		300,000.00	
Colburn Fund		93,310.45	
Reserve Fund		2,710,420.33	
Insurance Fund		272,429.09	
Pension Fund		76,543.85	
			$25,572,703.72
Plant Capital			3,186,498.38
Income Unexpended:			
Appropriations for remainder of 1919—			
Large Grants (Schedule 3)	$180,214.28		
Minor Grants (Schedule 4)	64,987.79		
Publications, Sundry Authors, etc.	71,374.50		
Administration	13,820.60		
		330,397.17	
Unappropriated		53,294.39	
			383,691.56
			29,142,893.66

Exhibit B.—Statement of Cash Receipts and Disbursements for the Year ended October 31, 1919.

RECEIPTS.

Interest from:		
Endowment—		
Bonds	$1,112,441.25	
Bank Balance	13,126 80	
		$1,125,568.05
Reserve Fund—		
Bonds	106,831.79	
Bank Balance	2,273.61	
		109,105.40
Insurance Fund—		
Bonds	10,073.73	
Bank Balance	366.80	
		10,440.53
Colburn Fund—		
Bonds	4,513.79	
Bank Balance	56.41	
		4,570.20
Pension Fund—		
Bank Balance		1,457.80
		1,251,141.98
Sales of Publications:		
Index Medicus	$4,267.95	
Year Book	93 30	
Miscellaneous Books	8,476.33	
		12,837.58
Refunds on Grants:		
Grants	53,549.98	
Unappropriated Fund	3,597.90	
		57,147.88
Miscellaneous:		
Carnegie Corporation of New York	210,000.00	
Sale of Paper	901.09	
		210,901.09
Total Receipts		1,532,028.53
Balance, October 31, 1918:		
Cash in Banks		509,383.77
		2,041,412.30

DISBURSEMENTS.

Investment:		
Securities	$437,561.82	
Collection Charges	1,398.47	
		$438,960.29
Pension Fund:		
Annuity Contribution	4,433.54	
Expense	1,005.40	
		5,438.94
Grants:		
Large	845,123.82	
Minor	123,371.90	
		968,495.72
Publication		68,964.23
National Research Council		75,000.00
Administration:		
Trustees	$1,413.03	
Executive Committee	1,719.01	
Salaries	32,951.10	
Shipping Publications	6,232.91	
Surety, rent, telephone	533.17	
Equipment	1,035.10	
Postage, express	703.64	
Printing, paper	5,378.35	
Office, petty expense, stationery	1,942.14	
Building and grounds—		
Supplies, janitors	2,433.64	
Fuel, light, water	1,400.74	
		55,742.83
Total disbursements		1,612,602.01
Balance, October 31, 1919:		
Cash in Banks		428,810.29
		2,041,412.30

Schedule 1.—Schedule of Investments at October 31, 1919.

Par Value	SECURITIES	Investment Value	Total
	Endowment.		
$21,200,000	U. S. Steel Corporation, Registered 50-year 5% Gold Bonds, Series A, B, C, D, E, F, due April 1, 1951	$21,200,000.00	
175,000	Chicago, Milwaukee & Puget Sound Railway Company, First Mortgage 4% Gold Bonds, due January 1, 1949	159,268.00	
14,000	Chicago, Milwaukee & St. Paul Railway Company, General Mortgage 4½% Gold Bonds, due May 1, 1989	13,953.75	
325,000	Lehigh & Lake Erie Railroad Company, First Mortgage 4½% 50-year Gold Bonds, due March 1, 1957	331,568.30	
237,000	New York City 4½% Registered Bonds, due March 1, 1963	253,557.50	
150,000	South & North Alabama Railroad Company, Consolidated Mortgage 5% Bonds, due August 1, 1936	160,875.00	
500	United States of America Third Liberty Loan	500.00	
			$22,119,722.55
	Colburn Fund.		
20,000	Acker, Merrall and Condit Company, Debenture 6% Bonds	13,600.00	
4,000	Chicago, Milwaukee & St. Paul Railway Company, General Mortgage 4½% Bonds, due 1989	4,070.00	
8,000	Park and Tilford Company, Sinking Fund, Debenture 6% Bonds	6,400.00	
50,000	Pennsylvania Railroad Co., General Mortgage 4½% Bonds, due June 1, 1965	51,062.50	
42,000	Pittsburg, Shawmut & Northern Railroad, First Mortgage 4% Bonds, due February 1, 1952	4,200.00	
5,000	United States of America Second Liberty Loan of 1917	5,000.00	
3,100	United States of America Third Liberty Loan of 1918	3,058.20	
3,100	United States of America Fourth Liberty Loan of 1918	3,036.64	
2,600	United States of America Victory Liberty Loan of 1919	2,600.00	
			93,027.34
	Harriman Fund.		
100,000	Southern Pacific Company, San Francisco Terminal, First Mortgage 4% Bonds, due 1950	100,000.00	
200,000	Chicago, Burlington & Quincy R. R. Co., Illinois Division, 4% Bonds, due 1949	200,000.00	
			300,000.00
	Insurance Fund.		
28,000	American Telephone & Telegraph Company, 4½% Convertible Bonds	28,978.00	
50,000	Atchison, Topeka & Santa Fe Railway Company, General Mortgage, 100-year, 4% Registered Gold Bonds, due 1995	50,056.25	
25,000	Bell Telephone Company of Canada, Debenture 5% Bonds, due April 1, 1925	24,760.00	
30,000	Chicago, Burlington & Quincy Railroad Company, General Mortgage 4% Bonds, due March 1, 1958	28,237.50	
1,000	Chicago, Milwaukee & St. Paul Railway Company, General Mortgage 4½% Gold Bonds, due May 1, 1989	995.00	
21,000	Great Northern Railway First and Refunding 4¼% Bonds, due 1961	20,944.00	
22,694,300	*Carried forward*	153,970.75	22,512,749.89

Schedule 1.—Schedule of Investments at October 31, 1919 (Cont'd).

Par Value.	Securities.	Investment Value.	Total.
$22,694,300	*Brought forward*	$153,970.75	$22,512,749.89
	Insurance Fund (Cont'd).		
21,000	Illinois Central Railroad Company, Refunding Mortgage 4% Bonds, due November 1, 1955	19,008.75	
24,000	Pennsylvania Railroad Company, Consolidated Mortgage 4½% Bonds, due August 1, 1960	25,095.01	
4,000	United States of America Second Liberty Loan of 1917	4,000.00	
29,500	United States of America Third Liberty Loan of 1918	29,500.00	
3,000	United States of America Fourth Liberty Loan of 1918	3,000.00	
32,400	United States of America Victory Liberty Loan of 1919	32,400.00	
			266,974.51
	Reserve Fund.		
50,000	American Telephone & Telegraph Company, Collateral Trust 4% Bonds, due 1929	45,500.00	
96,000	American Telephone & Telegraph Company, 4½% Convertible Bonds	99,456.25	
100,000	Baltimore & Ohio Railroad Company, General and Refunding 5% Bonds, due 1995	102,375.00	
50,000	Central Pacific Railway Company, First Refunding Mortgage 4% Registered Gold Bonds, due 1949	48,250.00	
150,000	Chicago, Burlington & Quincy Railroad Company, General Mortgage 4% Bonds, due March 1, 1958	141,263.75	
15,000	Chicago, Milwaukee & St. Paul Railway Company, General Mortgage 4½% Gold Bonds, due May 1, 1989	14,925.00	
120,000	Chicago and North-Western General Mortgage 3½% Bonds, due November 1, 1987	100,300.00	
155,000	General Electric, 5% Gold Debenture Bonds	158,213.47	
48,000	Great Northern Railway Company, First and Refunding Mortgage 4¼% Bonds, due 1961	48,109.25	
100,000	Illinois Central Railroad Company, Refunding 4% Bonds, due 1955	89,668.75	
280,000	Interborough Rapid Transit Company, First Refunding Mortgage 5% Bonds, due 1966	276,701.00	
50,000	Lake Shore & Michigan Southern Railway Company, Registered 25-year 4% Gold Bonds, due September 1, 1928	47,000.00	
50,000	Long Island Railroad Company, Refunding Mortgage 4% Bonds, due 1949	48,285.00	
50,000	New York, Westchester & Boston Railway Company, First Mortgage 4½% Bonds, due 1946	49,187.50	
50,000	Northern Pacific-Great Northern (Chicago, Burlington & Quincy Collateral), Joint 4% Bonds, due 1921	49,037.50	
50,000	Northern Pacific Railway Co., General Lien Railway and Land Grant 3% Bonds, due January 1, 2047	33,101.25	
50,000	Oregon-Washington Railroad & Navigation Company, First and Refunding 4% Mortgage Bonds, due 1961	46,375.00	
30,000	Pennsylvania Railroad Company, General Mortgage 4½% Bonds, due June 1, 1965	29,837.50	
101,000	Pennsylvania Railroad Company, Consolidated Mortgage 4½% Bonds, due August 1, 1960	105,608.12	
24,403,200	*Carried forward*	1,533,194.34	22,779,724.40

Schedule 1.—Schedule of Investments at October 31, 1919 (Cont'd).

Par Value.	Securities.	Investment Value.	Total.
$24,403,200	*Brought forward*	$1,533,194.34	$22,779,724.40
	Reserve Fund (Cont'd).		
100,000	Southern Pacific Railroad First Refunding Mortgage, 4% Bonds, due 1955	92,148.75	
140,000	Union Pacific Railroad Co. First Lien and Refunding 4% Bonds, due June 1, 2008	128,722.50	
112,500	United States Liberty Loan, 2d Converted 4¼s, due 1947	112,500.00	
85,500	United States of America Second Liberty Loan of 1917	85,500.00	
272,000	United States of America Third Liberty Loan of 1918	267,513.70	
364,000	United States of America Fourth Liberty Loan of 1918	357,181.30	
120,800	United States of America Victory Liberty Loan of 1919	120,800.00	2,697,560.59
	Pension Fund.		
50,000	United States of America Victory Liberty Loan of 1919	50,000.00	50,000.00
25,648,000			25,527,284.96

Schedule 2.—Schedule of Real Estate and Equipment at October 31, 1919.

Administration:		
Building, Site, and Equipment		$337,312.97
Department of Botanical Research (September 30, 1919):		
Buildings and Grounds	$31,816.94	
Laboratory and Library	17,869.27	
Operating Appliances	17,331.04	67,017.25
Eugenics Record Office (September 30, 1919):		
Library, Furniture, and Operating Appliances	$11,696.63	
Archives	45,368.52	
Buildings and Land	130,033.82	187,098.97
Department of Experimental Evolution (September 30, 1919):		
Buildings, Office, Library, and Grounds	$126,051.77	
Laboratory Apparatus	10,669.42	
Field	20,396.72	157,117.91
Geophysical Laboratory (September 30, 1919):		
Building, Library, Operating Appliances	$169,373.86	
Laboratory Apparatus	75,000.03	
Shop Equipment	10,888.36	255,262.25
Department of Historical Research (September 30, 1919):		
Office	$2,575.72	
Library	3,926.55	6,502.27
Department of Marine Biology (September 30, 1919):		
Vessels	$31,180.43	
Buildings, Docks, Furniture, and Library	12,120.36	
Apparatus and Instruments	8,745.30	52,046.09
Department of Meridian Astrometry (September 30, 1919):		
Apparatus and Instruments	$2,453.41	
Operating	2,146.37	4,599.78
Nutrition Laboratory (September 30, 1919):		
Building, Office, and Shop	$120,854.54	
Laboratory Apparatus	24,546.09	145,400.63
Mount Wilson Observatory (August 31, 1919):		
Buildings, Grounds, Road, and Telephone Line	$174,748.22	
Shop Equipment	37,533.51	
Instruments	422,056.26	
Furniture and Operating Appliances	134,679.57	
Hooker 100-inch reflector	516,903.30	1,285,920.86
Department of Terrestrial Magnetism (September 30, 1919):		
Building, Site, and Office	$145,391.62	
Vessel and Survey Equipment	145,730.18	
Instruments, Laboratory, and Shop Equipment	80,686.99	371,808.79
		2,870,087.77

REPORTS ON INVESTIGATIONS AND PROJECTS

The following reports and abstracts of reports show the progress of investigations carried on during the year, including not only those authorized for 1919, but others on which work has been continued from prior years. Reports of Directors of Departments are given first, followed by reports of recipients of grants for other investigations, the latter arranged according to subjects.

DEPARTMENT OF BOTANICAL RESEARCH.[1]

D. T. MacDougal, Director.

The fundamental features of growth, nutrition, and metabolism, especially of the carbohydrates, soil aeration, and the problems of physiology and phytogeography of plants of arid regions continue to claim the major part of the attention of the investigative members of the staff. The results of the activities of the year on subjects within the implied range are detailed on the following pages.

The improvement in industrial conditions early in the year made it possible to secure supplies and appliances not available during the war, although standardized instruments urgently needed in many fields of work are not yet readily obtainable. On the other hand, certain processes developed in connection with military activities are proving to be of value in facilitating research, as, for example, in the production of helium, the experimental use of which with organisms is described for the first time.

The earlier plans for field work in the arid regions of the Southwest have necessarily been curtailed and modified by the continuance of conditions along the Mexican boundary, which lies 60 miles to the southwest of the Desert Laboratory. Material for the solution of many major problems in phytogeography may be obtained only by free access to the regions between our base and the Gulf of California. Meanwhile, geographic work has been continued on the Californian coast and in a coastal mountain range and in Australia.

GROWTH AND HYDRATION.

Character of Protoplasm Fundamental to Growth, by D. T. MacDougal.

In my extended studies on growth, it has been necessary to go behind current assumptions as to the composition and nature of protoplasm and reconsider the data in older chemical determinations and to have new analyses made. Living matter, of course, may not be subjected to an analysis like a sample of ore or a mixture of salts, but its actual constitution must be inferred from the substances which may be obtained by chemical treatment. Its essential components are proteins, pentosans, lipins, and salts. The substances of the first two groups are of especial importance and together make up all but the minutest portion of protoplasts. The proportion which these two substances bear to each other largely determines the character of the living matter in any cell or in any organism.

The protoplast of the animal is highly proteinaceous, and this is also true of spores, bacterial cells, etc., in plants. The plant cell is mainly characterized by a predominance of pentosans. The metabo-

[1] Situated at Tucson, Arizona.

lism of a predominantly proteinaceous unit includes the derivation of amino-acids by breaking down albumins, while the amino-compounds may be synthetized in the plant in which the amination of the carbohydrates is the theoretical step in the construction of nitrogenous material.

The main components of living matter are not soluble or diffusible in each other, and they are therefore in an intimate non-homogeneous mixture in a colloidal condition in which the separate particles are so small as to give play to surface forces of great intensity.

Growth, as has been defined, consists of two processes. First, the molecules or aggregates of molecules of the two kinds, the carbohydrates and the albumins, combine with and absorb water, thus increasing the volume of these units, regardless of whether such particles be in the form of droplets or fibrillæ of a mesh-work. Instances of growth are known in which water only has been added to the colloidal structure in which in all probability the solid particles have been variously rearranged. In general, however, growth is accompanied by the accretion of molecules of solid material in such manner that as development proceeds their proportion to that of the water taken up increases, and organs are then said to show an increase of relative dry weight with age.

On the other hand, my own studies have shown that succulent organs or stems, such as leaves of the Crassulaceæ, joints of cacti, fruits, etc., do not show such increase, and the proportion of solid matter and of water undergo but little change, their incorporation being at a rate which keeps them near the initial proportion. It is suggested that such action may be shown by the fleshy fungi, although I have not seen any data bearing directly upon this matter.

The conditions under which hydration may ensue are by no means identical for the two main constituents of living matter. Thus, the albumins and their derivatives, as exemplified by the behavior of gelatine, show a swelling determined or facilitated by the hydrogen-ion concentration or acidity of the solutions, being increased as this rises. The pentosans, on the other hand, show no such increase, and, being weak acids, their hydration is retarded by the hydrogen ion. The swelling of a mixture of the two will therefore be a resultant of these effects and of the proportion of the two elements in the living mixture, and as the unceasing action of respiratory metabolism results in the formation of some residues of acids, the condition of hydration of any mass of protoplasm may be said to reach a volume determined by these opposed reactions. The fundamental properties of a colloidal mixture or of living matter will depend upon the proportion of albumins and of pentosans, and upon the properties of the particular substances of each group which may be present. Hydrogen ions within the possible range of concentration increase hydration of the albuminous

substances and depress that of the pentosans. Bases or cations exert a reverse effect on the albuminous substances and depress hydration of the pentosans slightly. Certain amino-compounds depress the swelling of albuminous compounds, but facilitate the hydration of pentosans, and dried sections of pentosan-albumin mixtures undergo hydration in solutions of these substances to a degree equivalent to or even greater than that in water.

As to the second phase of growth, that of the incorporation of molecules of solid matter, it is obvious that the mass of living matter may not be increased simply by the addition or diffusion of sugars into the mesh-work, as is supposed by some writers.

Before the material in these carbohydrates may actually become a part of the colloidal living mesh, it is undoubtedly broken down to some extent by enzymatic or respiratory action, part of the material being carried through transformations to organic acids or carbon dioxide; some of the material is combined with the ammonia group (NH_2) to form amino-compounds, some with the lipins, while some of these sugars may be converted to the pentosan form, in which they would so markedly affect the hydration capacity of the mass.

Protoplasm might be regarded as the wick of a lamp which draws sugar into its meshes, burns the sugar, and in the burning some of the sugar not completely consumed unites with other substances to form additional fibers of the wick, of which the pentosans or mucilages are examples.

The so-called "nutrient salts," in fact, yield no energy and furnish no building-material. They may act as catalyzers or as releasing agents, and as controls of water absorption or as guides in colloidal arrangement, but they are not "food-material" in any sense.

The enlargement of the individual masses of living cells in organisms entails a certain amount of work which in the earlier stages is derived almost entirely from imbibition or absorption, and while such action continues throughout the growth or life of the living matter, there is in addition the stretching action exerted by the expanding vacuoles by osmotic action. The growing regions of plants at all times include cells in all of these stages, from the newly separated protoplasm which is expanding entirely by imbibition of water and incorporation of new material, others in which the syneretically formed vacuoles are increasing and thus adding to the volume of the cell by osmotic action, and others approaching maturity, in which the vacuole may have attained such size as to occupy many times the space of the living matter, which may indeed now be but a sac with its layers of irregular thickness lying internal to the wall, which now has become dense and rigid.

Growth in plants is therefore a hydration expansion or swelling of a mass of pentosan-protein colloid or jelly which forms a sac or inclosing layer of greater density, which takes in water and solutions by adsorp-

tion, imbibition and osmosis being controlled or affected by the hydrogen-ion concentration, salts and amino-compounds of the cell sap, and also by the composition of the medium or substratum and other environmental conditions, such as temperature.

The Hydration of Biocolloids simulating certain Features of Protoplasm, by D. T. MacDougal.

Extensive experimentation with various biocolloids has given ample support to the conclusion that a mixture of carbohydrates and proteins may be made which will exhibit hydration relations similar to those of protoplasm.

Agar which has been specially purified for this purpose by E. R. Squibb & Sons has been found a useful pentosan, and others are cherry gum, acacia gum, and the mucilage of *Opuntia*. The last-named products are prepared by precipitation with alcohol, but the degree of purity of such preparations is not as great as that of the agar. These pentosans may vary not only in the proportions of the pentoses and hexoses present, but also in their acidity, which may be due to the presence of amino-acids.

The replacement of some of the agar in an agar-albumin mixture by one of these gums or mucilages modifies the swelling reactions, as illustrated by the data in the table on page 61.

The pH values were calculated from colorimetric tests after the method perfected by Dr. B. M. Duggar. Soy albumin was tested in a 0.5 per cent solution, gelatine in an 8 per cent solution, *Opuntia* mucilage, cherry gum, acacia gum, and agar in a 1 per cent solution.

Among other facts, it is to be seen that the hydration capacity of agar-albumin is less in water than other biocolloids in which some of the agar is replaced by another pentosan group.

Next it is obvious that the hydration in water, which was renewed at regular intervals, is not conditioned directly upon the hydrogen-ion concentration of the components.

The maximum swelling is greatest in the biocolloid containing the mucilage of *Opuntia*, which is at the same time the most "sensitive" of all the combinations, as its swelling in hydroxides, salts, and acids is very low, especially in the acids, a fact which corresponds to the inferred action of acidity in the living cacti.

The single salt used determines a hydration of gelatine less than in water, of agar and agar-protein half or less than in water, and when some of the agar is replaced by another pentosan the swelling capacity is lessened. The foregoing reactions are obviously of primary significance in the mechanics of growth.

The swelling of dried sections of the above mixture also yields some information as to the influence of deposition and other historical

features of a colloidal mass on its swelling reactions. The colloids in question are poured on glass, gold-foil, or filter-paper in a layer 0.8 mm. in thickness, and are prevented from shrinking superficially while coming down to a thickness of 0.11 to 0.2 mm. The result is a definite structure and a capacity for swelling determined by the conditions of

Percentage of swelling of biocolloids at 15° C. in water, acids, hydroxides, and potassium nitrate at 0.01M.

	Parts.	KOH, pH = 11.99.	NH_4OH, pH = 10.61.	KNO_3, pH = 6.6.	HNO_3, pH = 2.01.	HCl, pH = 2.01.	Water.
Agar Soy albumin 0.11 mm.	8 6.5 2 6.2	1,000	910	910	640	455	2,000
Agar Opuntia mucilage Soy albumin 0.14 mm.	4 6.5 4 5.8 2 6.2	530	700	1,310	600	440	2,785
Agar Cherry gum Soy albumin 0.17 mm.	4 6.5 4 5.1 2 6.2	700	1,000	1,400	650	685	2,415
Agar Acacia Soy albumin 0.16 mm.	4 6.5 4 5.1 2 6.2	700	750	1,400	650	600	2,100
Agar Acacia Gelatine 0.19 mm.	4 6.5 4 6.2 2 5.2	1,200	1,600	1,060	525	525	2,000
Agar 0.16 mm.	6.4	844	1,000	2,000	1,060	970	3,700 4,200
Gelatine 0.25 mm.	5.2	....	....	....	....	....	.....
Thickness	....	1,640	1,560	875	2,040	1,960	960
Volume	....	3,190	3,090	1,246	3,852	4,700	1,570

dehydration. Thus sections of agar and cherry gum, which swelled 2,400 per cent in thickness, extended only 4 per cent or less in water. Such action is not to be predicated of all colloids.

Gelatine plates prepared as above seem to take on a modification of this heterotropic structure. The increase in the length and width of a small section of such plates may be from 40 to 80 per cent or ten times as much as that of agar-cherry gum, yet it is not more than one fortieth or fiftieth of the expansion in thickness. This action may well be suggested as the physical basis of cytological performances in the plant cell.

The Effects of Organic Acids and Their Amino-Compounds on Hydration and Growth, by D. T. MacDougal and H. A. Spoehr.

The biocolloids of the plant are pentosan-protein mixtures in which the substances of these two main groups vary widely in their proportions, with a smaller proportion of lipins probably more or less localized. The variables are so large that generalizations concerning the action of the plasmatic mass are not easily to be founded. Of the more important assertions concerning the action of protoplasm, the earliest and most widely used, that protoplasm undergoes hydration like an amphoteric colloid and is exemplified by swelling gelatine, has long since failed to satisfy the experimental conditions or to offer parallels to the action of cell-masses of the higher plants.

If protoplasm were entirely or dominantly proteinaceous, the actual acidity or hydrogen-ion concentration might be taken as the chief factor in maintaining the rate and determining the course of hydration and growth. The predominance of the pentosans in plant cells, however, offers a set of conditions much more complex than that of the comparatively simple ionization of gelatine, for, as has been noted, the conditions which facilitate the action of protein gels retard and limit the hydration of the carbohydrate gels to an extent and in a manner which depend upon the structure and character of the pentosans present.

The results of Borowikow and of Dachnowski show that the growth of plants, the higher green forms, does not depend upon the hydrogen-ion concentration alone. Acids and bases both influence hydration and growth. In addition, the accelerating effects of amino-acids and amines on hydration of biocolloids and cell-masses, living and dead, go far to support the conclusion that these substances facilitate or increase total growth. These substances are built up from simpler substances in the plant in a manner which is by no means clear, although under investigation and discussion for a quarter of a century. The evidence favors the assumption that they come together in the field of photosynthetic activity. These amino-groups occur only as disintegration products of the proteins or albumins in animal metabolism.

The total amount of amino-compounds in a cell-mass of a plant varies widely during the course of a day, and, as has been noted above, the proportion of nitrogenous material in the organs of the cell or the members of a shoot may be greatly different.

As the hydrogen-ion concentration of the sap is known to remain fairly constant, as the salts or bases which affect growth also change but slowly, attention naturally focuses on the amino-compounds as a factor in modifying the rate, course, and total amount of growth. As the acids and their salts may be assumed to act invariably in the presence of amino-groups, a series of tests was planned which should make possible a comparison of the action of some of the commoner organic acids and their amino-compounds.

Two groups were chosen for the tests: succinic acid and its amino-compound, amino-succinic or aspartic, which are dibasic, and its amide as noted above, which is monobasic, and acetic acid and its amino-compound, glycocoll, which are monobasic. Sections of plates of agar, gelatine, agar-gelatine, agar-protein, and other mixtures were used. Swellings were carried out in the equable-temperature chambers of the Coastal Laboratory at 16° to 17° C. A compilation of the principal results is given in the following table:

Hydration of agar, gelatine, agar-gelatine, and agar-oat protein in organic acids and their amino-compounds at 16 to 17° C.

[Expansion in percentages of dried thickness.]

Concentration.	Succinic acid. Mol.	Aspartic acid. Mol.	Asparagin. Mol.	Acetic acid. Normal.	Glycocoll. Mol.
Agar:					
0.3	....	....	....	....	1,950
0.5	....	....	....	1,060	2,804
0.1	....	1,000	2,260	1,333	....
0.05	1,091	827	2,308	1,433	....
0.01	1,273	1,270	2,365	1,560	2,965
0.002	1,600	1,400	2,440	1,790	3,166
0.0004	1,750	1,788	2,720	1,955	2,605
0.00008	2,528	2,080	3,250	2,640	....
Water: Av., 2,600 p. ct.					
Gelatine:					
0.1	....	....	....	....	....
0.05	1,200	1,500	320	952	370
0.01	700	1,033	480	714	....
0.002	500	380	500	690	360
0.0004	433	340	467	643	360
Water: Av., 600 p. ct.					
Agar 8 parts, gelatine 2 parts:					
0.5	....	....	....	....	....
0.1	....	....	....	850	....
0.05	716	910	1,485	850	1,233
0.01	850	1,017	1,574	900	1,960
0.002	917	1,295	1,308	922	1,767
0.0004	1,000	1,667	1,383	1,117	1,420
0.00008	1,030	1,786	1,383	1,167	1,484
Water: Av., 1,684 p. ct.					
Agar 8 parts, Oat-protein 2 parts:					
0.5	....	....	....	500	....
0.1	....	....	....	809	....
0.05	700	855	1,867	1,090	1,938
0.01	864	900	2,455	1,255	2,340
0.002	909	1,670	2,523	1,738	3,050
0.0004	1,136	2,600	2,675	2,238	3,000
0.00008	2,330	3,050	2,600	2,480	....
Water: Av., 2,365 p. ct.					

The deductions to be drawn from these figures, all being averages of 3 to 9 measurements, are numerous, but attention must be confined to a few pertinent cases.

(1) It is to be seen that equimolecular concentrations of the three organic acids present small divergence of effect on agar and more positive differences in agar-protein.

(2) Agar swells more in succinic acid than in its amino-compound, but reverses this relation notably in the acetic-glycocoll couple.

(3) The agar-protein biocolloid shows notably greater hydration in the amino-acids than in the related organic acids, and greater even than the hydration in distilled water.

(4) Equimolecular concentrations of amino-acids produce notably greater swellings of the biocolloids in comparison with related organic acids implying the positive action of factors other than the hydrogen-ion concentration.

(5) Glycocoll facilitates hydration in all concentrations above 0.01 M. in both agar and agar-proteins, and also in agar-gelatine, the data of which are not given in this paper. This fact goes far in explanation of the scattered results obtained by various workers, in which accelerated growth or increased total growth has been seen to result from the addition of glycocoll to nutrient solutions. Such increases have been attrituted to catalytic action by Dakin and others.

(6) The amine, asparagin, induces a maximum hydration, greater even than that possible in agar in distilled water, and very high at all concentrations. Similar action was exerted on agar-gelatine and agar-protein plates. The positive action of both glycocoll and asparagin is indicated by the fact that the maximum effect is reached at certain concentrations above the minimum concentration.

The Solution and Fixation accompanying Swelling and Drying of Biocolloids and Plant Tissues, by D. T. MacDougal and H. A. Spoehr.

The hydration of a colloidal mass, whether it be a dried plate of a biocolloid, a dried plant-section, or a mass of living protoplasts, is all but invariably accompanied by the solution or extraction of some of the substances of the colloidal mass. The material found in such extracts will in all cases be determined by the diffusibility of the compounds present. These diffusions encounter highly specialized conditions at the external limits of the protoplasts, where a colloidal phase boundary separates the elastic gels and highly viscid emulsoids of the pentosan-protein-lipoid protoplasm from the denser, more rigid cellulose-pectose walls inclosing the cells.

In the course of some work on the imbibition and growth of plants, the analyses of which show that the water relation of the protoplasm is determined by the pentosan-protein proportion, and that the activ-

ities of such living material are not to be simulated by the imbibitional action of the amino-compounds of gelatine, attention was paid to the following matters:

(*a*) Extractions from living cell-masses.
(*b*) Extractions or solutions of sections of biocolloids.
(*c*) Acidity of fresh or living tissues.
(*d*) Acidity of desiccated tissues.
(*e*) Swelling of fresh sections.
(*f*) Re-swelling of extracted and dried tissues.
(*g*) Swelling of dried tissues.
(*h*) Repetition of swelling and drying treatments.

These treatments as applied to median slices of maturing joints of *Opuntia discata* grown at Carmel gave measurements as below at 18° C. The flat joints at 10 to 12 mm. in thickness and the median portion include but little chlorophyll. Sections suitable for swelling, free from any except the smallest fibro-vascular strands, were readily procurable.

The solution of material from a section of a plant with its thousands of cellulose walls presents physical features that are not easily to be duplicated. Amino-acids, hexoses, malates, and salts, however, constitute the bulk of the extracted material, together with other substances set free by the bursting walls of some of the cells, in addition to those crushed in taking out the section. Diffusion of the pentosans would take place slowly, although the derivation of large proportions of this material by extraction after killing with ether suggests that the rate is not inconsiderable and may be subject to various modifications.

The lessened hydration capacity of a section previously extracted is probably a resultant of various losses. The amino-acids mixed with the pentosans form a colloid with a high hydration coefficient. The salts and free acids would operate to limit imbibition of a carbohydrate-protein colloid and their extraction would remove this limit. Extraction may therefore remove acids and salts which lessen swelling, and at the same time some amino-acids which give to pentosans a high hydration capacity. The second swelling of a section of a plant may therefore represent a series of reactions widely different from those of the first treatment.

We are indebted to Professor H. M. Richards for determinations of the acidity of the water in which fresh slices of *Opuntia* were swelled, and it was found this might be expressed as follows: 10 c.c. solution from dish in which set of fresh sections were swelled in water = 0.44 c.c. N/20 KOH. Dried slices of the above material, when swelled in water 24 hours, gave a solution the acidity of which might be expressed as: 10 c.c. of solution = 0.10 c.c. N/20 NaOH. When such sections were immersed in citric acid 0.01 N., the strength of the solution was increased so that at the end of 24 hours the acidity was expressible as 10 c.c. of solution = 2.25 c.c. N/20 NaOH.

The rapid penetration of cell-masses by acids is a well-known reaction and is accompanied or followed by the extraction of electrolytes, and it has been held by some authors that when the preliminary swelling which takes place in acids changes to a shrinkage death is implied. This last distinction is one without special meaning in connection with the present paper.

The hydration of colloidal plates, of dried sections of plants, and of fresh sections presents parallel reaction in hundredth normal organic acids. The chief features of such swellings consist in an initial rapid expansion followed by shrinkage due to solution or dispersion of the sections. The swelling of the pentosan, agar, which has been used so widely in the imbibition measurements in connection with growth, would be accompanied by the solution or dispersion of material of the external part of the sections and by the diffusion of whatever salts or acids might be present in the interior of the mass.

A test was carried out to determine what such loss might be in sections of agar and in a simple biocolloid. The agar was cast in plates which came down to 0.25 mm. in thickness from a 2.5 per cent solution. Strips equivalent to 200 sections, with a surface of 2,520 sq. mm., were now placed in beakers of distilled water, 10 c.c. to each section of 12 sq. mm., for a period of 24 hours, at the same temperature. The evaporation of the water showed 0.2570 gram of material had been dissolved from the plates or sections which weighed 1.6731 grams at the beginning, which was equivalent to about 15 per cent. This proportion is to be contrasted with the 7 per cent of the soluble material dissolved from sections of *Opuntia*, allowing for the non-soluble cellwalls.

Another series of extractions was made with sections of biocolloids consisting of 8 parts agar and 2 parts gelatine, which were heavier, having a thickness of 0.38 mm. Strips of this material weighing 1.0316 grams, with a surface of 2,542 sq. mm., were placed in water at temperatures as above for 24 hours, and when this was evaporated a residue of 0.1865 gram was found, which was equivalent to about 18 per cent of the original. Most of this and of the material dissolved from agar sections in all probability is derived from the surface layer of the material, as both gelatine and agar are so nearly non-diffusible as to render their extraction from the interior of the section all but impossible.

A test was arranged to estimate the relative amount of material which might be extracted from plant tissues by a treatment which would parallel the immersions used in obtaining swelling measurements. Sections of joints of *Opuntia* have been used extensively in work on swelling, and in order to obtain sufficient material, 24 of the customary size for testing under the auxograph were placed in 250 c.c. of water at temperatures of 16° to 18° C., at which swellings under instruments were also made. At the end of 24 hours the mucilaginous solu-

tion was measured off, 50 c.c. being allotted for acidity determinations (see results above), and 180 c.c. was used for determination of the solid matter present. It was found that this amounted to 0.28 gram for the 240 c.c. of juice obtained from sections having a total volume of 40 c.c. when fresh. The actual solid matter of the sections, including the cell-walls, may be taken as 10 per cent of the whole, or as 4 grams. Of this, 7 per cent was dissolved out in water. The extraction of this amount of material could readily be held to account fully for the changes which take place in hydration and which give different expansions in the second immersion.

It is quite clear that no explanation of absorption of solutions by cell-masses or of plasmolysis may be adequate or greatly useful which does not take into account certain fundamental mechanical features of the cell-structure. Among these are to be included the phase boundaries of the colloids of the cell-wall, of the vacuoles, of the protoplast, and of the multiple and varying structures in the protoplasm.

Plasmolysis by osmotic action is accompanied by losses and by penetrations and perfusions of complex character in the many phases of the cell colloids. Plasmolysis in wilting is in some respects a simpler matter. Vaporization of water from the cell-walls is followed by replacement movements from the cell colloids, which result first in a lessened volume of the protoplast and finally in the progressive concentration of all substances, especially those dissolved in the vacuoles, and in the more liquid phases of the colloids. The fact that the acids may be readily extracted in greater proportion from dried specimens than from fresh tissues suggests that these substances may have crystallized out to some extent after the manner of amino-acids incorporated in colloidal mixtures. The same may be true to some extent of the salts. There is also much in favor of the conclusion that changes take place in the colloidal mesh, as a result of a loss of water and of the action of adsorbed bases which cause coagulations not reversible by simple hydration.

Measurement of Growth in Terms of Volume, by D. T. MacDougal.

Measurement of growth in the higher plants usually denote the rate of increase of stems, roots, etc., in which the variation in length or thickness is taken without reference to the volume of the enlarging cell-masses. The growing joints of *Opuntia* offer some features for more exact computations, but the rounded or globular fruits offer the best material for a consideration of the actual and relative accretions to the enlarging organs.

The usual method of expression of increase in a tomato would be in terms of varying diameter, but the actual increase is to be calculated from the formula $V = 4/3\,PiR^3 - 4/3\,Pir^3$, in which r = the radius at the beginning of the measurement and R = the increased diameter, the

fruit being taken as a globe. The relation of the two sets of measurements is to be seen by comparison of the data in section A of the table.

Average daily rates of growth by increase in diameter and by volume.

A. First fruit.			B. Second fruit.			C. Third fruit.		
Period beginning.	Increase in diameter.	Increase in volume.	Period beginning.	Increase in diameter.	Increase in volume.	Period beginning.	Increase in diameter.	Increase in volume.
	mm.	*cu. mm.*		*mm.*	*cu. mm.*		*mm.*	*cu. mm.*
Aug. 9..	1 7	2,604	Aug. 9..	0.95	717	Aug. 21..	0.85	716
16..	1.1	1,847	16..	0.7	1,851	28..	0.85	1,135
21..	0 7	2,064	21..	0.56	1,698	Sept. 4..	0.64	1,180
28..	0 4	1,381	28..	0.3	1,391	11..	0.8	1,391
Sept. 4..	0.28	976	Sept. 4..	0.2	507	18..	0.3	792
11..	0.17	695	11..	0.2	560	25..	0.37	883

The rate on September 11 by direct measurement would appear to be one-tenth that of a month earlier, yet actually water and new material were being added at a rate equivalent to one-fourth of the earlier rate. The radial proportions would make the rate on August 21 not much more than 40 per cent of the rate on August 9, while the increase in volume was over 96 per cent. The rate in the week beginning August 28 would appear to be less than a fourth that by direct measurement on August 9, yet actually the increment of water and material is more than half that in the younger stage and smaller size.

A second fruit, with the auxograph bearing arranged to take axial variations in the fruits which measured 33 mm., was arranged to run concurrently with the above and under identical temperature and conditions of moisture. The daily rates of increase in diameter were as shown in section B of the table.

During the first three weeks the rate of increase in diameter lessened, while the actual accretion increased during this time. During the last two weeks the increase in diameter was the same, but the accretions increased.

The daily rate of increase of a third fruit was as shown in section C of the table.

The actual volume of this fruit at the close of the experiment was approximately 22,000 cu. mm. and its growth had been followed for a period of 40 days. It is notable that in the earlier stage, in the advance of the fruit from 20 to 26 mm. in diameter, while the increase of the diameter seems constant, the actual accession of material is very much greater. Then in further development the average increment to the diameter was smaller, yet the actual accession of material was greater. Following this, the rate falling from 0.8 to 0.3 mm. daily, the accession decreases less than half.

The Daily Course of Growth in Two Types of Fruits, by D. T. MacDougal.

Two different types of organs or shoots with respect to the variations in the water-content and dry weight are recognizable. The commoner types of woody stems, thin leaves, and the organs of the greater number of the higher plants undergo a development which terminates in a mature stage in which the proportion of solid material is very much higher than that found in younger material. A parallel procedure is the prevalent one in the tissues of the higher animals.

Etiolated plants furnish examples of growth with a diminished increase in dry weight, but chief interest attaches to plants which normally show such action, and the most striking illustrations are to be furnished by the organs of succulent plants and by fruits. The relative amounts of solid material in the flattened joints of *Opuntia* do not increase with the course of development toward maturity, and joints which have reached full size may contain over 91 per cent of water. Secondary thickening, especially that which results from branching and the development of additional fibro-vascular tissue, may cause an added amount to be formed. The proportion of dried material and water in the leaves of *Mesembryanthemum* does not vary greatly with age. Extended discussions of the growth of these succulents have been given in previous publications of this Department. Following a full recognition of the two types of growth in 1918, a final series of experiments was arranged in which the enlargement of fruits with increasing dry weights and with small dry weights should be measured. The walnut was taken to represent a structure with accumulating solid matter and the tomato for the other type.

The walnut consists of a thick fleshy exocarp and a heavy endocarp which finally becomes hard and bony with the deposition of anhydrous wall-material. The inclosed embryo also accumulates a large amount of condensed food-material. The tomato is a large globose berry in which deposition and thickening is confined to the small, hard seeds. The greater part of the fruit is a fleshy, watery pulp, which becomes more highly hydrated as progress is made toward maturity.

The measurement of walnuts, beginning at a stage when they had a diameter of but 3 mm. and extending to maturity, showed that these nuts displayed a daily variation corresponding with the balance between transpiration and absorption of such character that enlargement began after noon and continued until sunrise, at which time a retardation or shrinkage set in, which continued until midday. It is notable that the young growing nuts exuded water when cut into, and were so nearly saturated that they showed but slight swelling in water, drew their supply from stems with such a water deficit that a swelling of 10 per cent was displayed, and an amount of water equivalent to 25 per cent of their volume might be taken up when immersed. Such absorp-

tion could of course take place only by the absorptive or imbibitionary action of colloids rather than osmosis.

The fruit of the tomato (*Lycopersicum*) presents some daily variations similar to the walnut and is characterized by a dry weight which lessens proportionately with development. Four fruits less than a week old, with radial diameters of 14, 16, 17, and 18 mm., were found to weigh 14.650 grams. These were fragmented and dehydrated, showing a dry weight of 1.90 grams. From this it is to be seen that the young fruit contained 87 per cent of water and 13 per cent of dry material. Mature fruit of the same kind weighed 93.050 grams and contained 8.400 grams dried material, being 9 per cent of the total. These watery fruits showed in a very marked manner the effect of water-loss or transpiration on the growth of the fruits. As the daily temperatures of the fruits rose from 12° and 14° C. to 26° and 28° C., acceleration ensued up to a point where the rise caused a water-loss overbalancing the gain by hydration. Higher temperatures, therefore, did not facilitate or accelerate growth unless accompanied by high relative humidity. Thus, the highest rates are those of midday and afternoon, with fog and showers. This is especially marked in a record in which a 50-hour rainy period was anticipated and followed by high humidity. It was not possible to increase the water-supply by watering the soil around the roots in such manner as to cancel the midday shrinkage or slackening in growth at other times. One especially striking effect is that in which the rise in temperature consequent upon the cessation of the rain from 20° to 25° C. at 3 p. m. was followed by a lessened rate of growth, and the rate on the cloudy days was uniformly high.

The water deficit of the stems as measured by swelling includes that of the entire structure. The fruits, however, receive their supply through special conduits which sustain only a mechanical relation to the other parts of the stem, which may be active in its swelling. Such non-conducting tissues of course draw their supply from this system of conduits also, but it is highly probable that the disproportion between the water-content of the fruit and of the tracts in the stem from which it receives its supply is not so great as might be indicated by the measurements given. The hydration capacity of the fruits would be the resultant of many factors, including the pentosan-protein ratio, the hydrogen-ion concentration, the action of salts, and the effect of the amino-compounds, and the course of growth does not follow the above daily procedure in all plants. I have described in previous publications the manner in which the concurrent action of transpiration, hydration capacity of the cell-colloids, and temperature cause the highest rate of growth in *Opuntia* in the daytime. This behavior is conditioned on the fact that the cacti show the greatest transpiration at night, at which time the acidity rises until it is ten times as great as in the daytime.

Influence of Soil Aeration upon Growth of Shoots, by W. A. Cannon.

In connection with studies on the direct reaction of roots to aeration conditions of the soil, which have been reported from time to time, work has been begun on the influence of soil aeration as a factor in the growth of shoots. This as an environmental factor of plants has not been properly evaluated. It is impossible to tell by inspection, or field studies, in what way and to what degree the aeration of the soil affects growth of the shoot. Because, for example, plants may occupy porous soils, it does not necessarily follow that the oxygen requirement of the roots is high. That, as a matter of fact, adequate aeration is necessary in some species to water absorption is known,[1] and it is also known and reported[2] that different species of land plants which may live in the same community may nevertheless have unlike root-oxygen relations. Such being the case, it is expected that survival may in some instances be found to be largely bound up with the relation of the roots to oxygen in the atmosphere of the soil. It must be considered especially important in this connection, particularly where oxygen deprivation causes cessation of the growth of the root, to determine the relation of this fact to the possible continuation of the growth of the shoot, as well as to determine the relation of the growth of the shoot under such circumstances to environmental factors, aside from and in addition to inadequate soil aeration. In fact, the general relation of the plant to soil aeration is of very great ecological importance and merits investigation.

In the preliminary experiments, a variety of garden forms have been mainly used, and in addition a potato hybrid, *Solanum fendleri* × *S. tuberosum* F_3[3], and *Eriogonum* sp., a species native to the vicinity of the Coastal Laboratory, were experimented with. The methods used were the same as in the case of the root-soil-air studies above referred to, with the addition of the employment of a MacDougal auxograph to record shoot-growth. Nitrogen was used to replace the soil-air. The experiments were conducted in the greenhouse at the Coastal Laboratory and the shoots were exposed to the ordinary conditions obtaining in the house. The following are some of the leading results:

In all of the plants of which the behavior of the root was observed, root-growth ceased in an atmosphere of nitrogen, although in certain species it continued 24 hours or over in such an oxygen-free soil atmosphere.

Usually the replacement of the ordinary soil-air by nitrogen induces a slowing of the growth-rate of the shoot. Upon the renewal of the usual soil-air conditions, shoot-growth increases in rate, and may become normal, provided the exposure to nitrogen has not been of

[1] Carnegie Inst. Wash. Year Book for 1916, p. 78.
[2] *Ibid.*, p. 74; 1917, p. 82; 1918, p. 81.
[3] Carnegie Inst. Wash. Year Book for 1918, p. 87.

excessive length. Where the roots have been deprived of oxygen an excessive length of time and are injured thereby, a delayed recovery on the part of the shoot may be related to the necessity of forming new roots upon the return to normal conditions of soil aeration. A few selections can be made of typical experiments where the growth of the shoot has been affected by inadequate root aeration.

In the case of the cultivated sweet pea, culture No. 5 with this form, shoot behavior was observed 3 days. The roots were in normal soil-air the first and last days and in nitrogen continuously the second day. In this experiment root-growth ceased in nitrogen and did not begin again during the course of the experiment. The shoot grew as follows: first day, roots in normal soil-air, 7 mm.; second day, roots in nitrogen, 3.7 mm.; third day, roots in normal soil-air, 8 mm.

The results of work with the cultivated sunflower, on the other hand, were not so consistent. Both root and shoot growth appeared to continue longer, however, than in the sweet pea or the garden bean.

Shoots of *Eriogonum* sp., with the roots continuously in nitrogen for 8 days, had a daily growth-rate as follows: 8 mm., 11.3 mm., 8 mm., 13.3 mm., 15.5 mm., 11.7 mm., 13.5 mm., and 8.5 mm. In this instance the temperature of the air as well as of the soil did not vary over 1° C. in any day.

The shoots of the potato hybrid, with the tubers still attached, ceased growth very promptly upon the replacement of the ordinary soil-air with nitrogen, or at least the growth-rate very markedly declined. For example, in the experiment with culture No. 6 of this form, the shoot increased 3.9 mm. in length in 41 hours, while the tuber and roots were in normal soil-air, but during the subsequent 70 hours, when nitrogen was used, the shoot-growth was only 2.3 mm., and this occurred mainly at the commencement of the gas administration.

In the morning-glory, *Ipomœa* sp., exposure of the roots for 48 hours to nitrogen did not stop shoot-growth, although it slightly checked it.

The shoot of tomato continued to grow, but at a decreasing rate, for 4 days with root in nitrogen, and on the fifth day, when air was again run in the culture, the growth-rate immediately increased.

The roots of corn were exposed to nitrogen for 4 consecutive days, and on the fifth day air was introduced. The daily growth amounts of the shoot are as follows: 13.7 mm., 14.5 mm., 6.5 mm., 4.5 mm., 3.0 mm., and in air, 2.9 mm. In this case a renewal of a normal shoot-growth rate would probably not be expected before fresh roots were formed.

The Dendrograph, by D. T. MacDougal.

Two designs for a dendrograph which would obtain a continuous record of growth and other changes in volume of tree-trunks during an entire season were used in the construction of working models which were used in preliminary tests on pines and oaks in 1918.

One of these designs was taken for immediate development. Six instruments were completed early in the year, and these were attached to trees at Baltimore, St. Louis, Tucson, Santa Catalina Mountains, Arizona, and Carmel, California, as described below, with the result that the seasonal activities of six species of trees during one season are now included in the records.

These measurements were made of the bases of trunks of trees 30 to 45 cm. in diameter at a height of 1.2 to 1.5 m. above the ground, and are therefore directly comparable to the figures obtained by the tape-line and calipers of the forester.

The variations of the base of a trunk are, however, but an imperfect index of the activities of a tree, and any adequate study of the physics of growth, the formation of wood, the development of bark, or the ascent of sap must be based upon measurement of the entire trunk or "cone" of the stem. It has been important, therefore, to construct an instrument which might be attached to trees at various heights up to 50 or 60 feet above the base, which would be so perfectly automatic as to need a minimum of attention. This has been accomplished, as evidenced by the fact that an instrument attached to a Chihuahua pine at an elevation of 6,000 feet, at a distance of 22 miles from the Desert Laboratory, was put in place during the first week in April and has made a perfect record during the season of 200 days, with no attention except a weekly visit to remove and replace record slips and wind the clock of the recording drum.

The essential part of the dendrograph is a "yoke" constructed of strips of some alloy, such as bario or invar, with a low temperature coefficient, 25 by 0.2 cm., arranged in the form of a U or of a polygon in such manner as to inclose the tree-trunk, with a clearance of 2 to 5 cm. on all sides. At one side (on the curve of the U) two contact-screws work in a horizontal position to a suitable pressure on seatings in the bark. The bearing end of a short lever seated on the instrument bar which bridges the end of the U or closes the polygon makes a contact on the opposite side, and any variations in the diameter of the tree between the end of the lever and of the two contact-screws (considered as one) will cause movements of the lever which will be transmitted to the pen arm which traces an inked line on the recording drum.

The yoke and the recording instrument are supported by a belt of hinged wooden blocks which have been boiled in paraffine. Sections of spring brass 1 mm. in diameter and 8 cm. long, fastened in small brass plates seated on the blocks, form a flexible support for the yoke and hold it with an adjustable tension. The recording instrument, of a design recently perfected for this use and with the auxograph, is seated on a large block which closes the circle of the belt. The lever system of the recorder engages the free end of the bearing lever on the instrument bar of the yoke and records all variations in diame-

ter. The only adjustments during the season are those which may become necessary by the enlargement of the tree.

A further study is being made of encircling flexible bands which might be used to replace the yokes in certain cases.

Growth of the Arizona Ash, by D. T. MacDougal.

An Arizona ash (*Fraxinus arizonica*), 14 years old, in the grounds of Dr. H. W. Fenner at Tucson, was selected for measurement. This tree had been transplanted to this place when 2 years old and was subject to irrigation, a condition not unusual to the tree in its habitat along streamways. The trunk was slightly compressed in one diameter and had a circumference of about 1 meter. An instrument with a yoke of bario was adjusted to this tree on March 8, 1919, at which time the flowers (staminate) were beginning to open, but no leaf-surface had yet been displayed.

Enlargement of the trunk began about March 10, although the enormous daily variation in this tree made it difficult to fix upon the day in which the increase was greater than the shrinkage. Enlargement was interrupted for 6 days early in April, probably due to low temperatures following a rainstorm, and in the latter part of July the increase had been such as to jam the lever, giving a record simulating shrinkage. Readjustment of the yoke and its bearing-points was followed by records showing growth. Enlargement had ceased by the end of October, at which time a total net increase of about 43 mm. had taken place, showing that this young tree, which had made an average increase of an inch in diameter yearly, was now approaching its maximum stage of activity.

The bearing-points of the yoke were seated on prepared places in the bark which had been thinned down to 1 mm. at the beginning. No examination has yet been made to ascertain what bark formation may have taken place at these places, but it may be safely estimated to amount to not more than 1 or 2 mm.

The daily variation in thickness of the trunk, the difference between the diameter at sunrise and at 4 p. m., was such as to indicate a shrinkage of as much as 0.4 mm. daily in March, and the increase by the following morning was 0.6 mm. In mid-April the shrinkage amounted to 1.1 mm. and the overnight increase 1.4 mm. This type of variation reached its maximum about May 1, when the daily shrinkage was as much as 1.6 mm. and the following swelling as much as 2.1 mm. This wide variation, which can be ascribed only to direct water-loss, was probably controlled or lessened by the formation of new corky tissues, although this matter needs morphological confirmation. The daily shrinkage during the summer rainy season was reduced to a minimum of 0.1 mm. or even less, and was not more than 0.2 or 0.3 mm. in any day during the remainder of the season.

The care of this instrument and of the records of temperature were shared by Dr. H. W. Fenner in May and June, and the entire experiment was in the hands of Mr. B. R. Bovee during June, July, and August. Mr. Bovee also made weekly trips to the instrument attached to the Chihuahua pine, 22 miles distant, with a climb of 4,000 feet.

Growth of the Chihuahua Pine, by D. T. MacDougal.

A dendrograph with a yoke of bario was carried by pack animals up a trail in the Santa Catalina Mountains in Arizona and attached to a tree of *Pinus chihuahuana*, 40 cm. in diameter, on April 4, 1918. This tree stood at an elevation of about 6,000 feet, at the extreme lower margin of its habitat. Some enlargement was exhibited from April 14 to May 4. After a period of quiescence and shrinkage, enlargement again began on May 28 and continued to June 14. A second period of quiescence intervened, with marked shrinkage during late June, which continued well into the summer rainy season, enlargement not being resumed until July 20. This continued until mid-October.

The increase of the trunk and included bark during the first period was about 2 mm., of which 1 mm. was lost in the ensuing quiescent period. A gain of 2 mm. was made in the second period, with a shrinkage of 3 mm. during the hot midsummer period preceding the summer rains. While presumptively some wood may have been formed, the diameter on July 20 was no greater than on April 4. An increase of 3 mm. had taken place by August 16 and was still in progress on that date. The daily variation was of the type which is described for the Monterey pine in the following paragraph. The shrinkage was greatest late in June, before the midday formation of cumulus clouds began, and the cambial region at this time took on temperatures of 25° and 27° C.

The fact that enlargement did not begin until after 3 weeks of the summer rainfall had passed is of no small interest. The temperatures of the cambial region at this time were about 18° and 20° C. Young cones had been formed and the pollen crop shed before measurements were begun, and some elongation of the branches had taken place. It is to be noted that the trunks of this tree show a double annual ring, a fact discovered and described by Dr. Shreve. (The density of stand and rate of growth of Arizona yellow pine as influenced by climatic conditions. Jour. Forestry, vol. 15, 695–707. Oct. 1917.)

The Growth of the Monterey Pine, by D. T. MacDougal.

The Monterey pine (*Pinus radiata*), which is native in a restricted region within a short radius of the Coastal Laboratory, is noted for its rapid growth and short life period. The conditions about Carmel are such that the species shows growth practically throughout the year,

either in seedlings, tips of branches, leaders, or trunks, although so far no member has been measured which shows continuous growth.

The auxograph records of the leader and of laterals of young trees showed elongation during August, September, and October 1918, with a decrease, retardation, or shrinkage during the midday periods, when water-loss was excessive, the general course of variation being parallel to that of the base of the trunk, as described below.

The action of the main stems 1 year old of trees 3 m. in height presents a special case. Such a stem, about 2.4 cm. in diameter, still bore leaves, had an unbroken epidermis, a chlorophyllose cortex layer over 1 mm. in thickness, a heavy cambial layer, the rays still composed of living cells, and a medulla or pith 3 to 4 mm. in diameter. The mechanical features presented may be roughly compared to those of a sunflower stem which had attained its growth in length but not in thickness.

The record of this stem was begun August 5, 1919, and nothing is known concerning its behavior earlier in the season. In August, September, and October, in which period some increase in thickness took place, the daily variations were the reverse of those displayed by the trunk, as an abrupt expansion began at 9 a. m. and continued for 3 or 4 hours, after which a retardation or shrinkage ensued.

The instrument was adjusted to the same position in May 1919, and this young stem, now 2 years old, was seen to enlarge at an irregular rate throughout the season; the daily variation was of the type in which the greatest enlargement occurs during the midday period.

The measurements of the base of the trunk of this pine were made on a tree about 42 cm. in diameter, and a yoke was adjusted to it at a height of 1.3 m. on March 24, 1918. Reproductive organs had been formed earlier, the crop of pollen had been shed a month earlier, and the tips of branches had elongated 3 or 4 cm., while the leaders of young trees had grown ten times as much. It appeared, however, that the base of the trunk had not begun to enlarge, as no increase was recorded until March 30.

The first interruption of growth occurred during a period of high temperatures and low humidity at the end of May, after which time the rate was lower and subject to long interruptions, although increases occurred as late as September, during which time the trunk, including the thin layer of inner bark under the contact points, underwent a total increase in thickness of 9 mm. or over a third of an inch. The actual thickness of the shell of wood or "annual ring" may be safely estimated at about 3 mm. The daily variation in thickness was such that in the earlier part of the season the actual diameter of the trunk at 2 p. m. might be 0.5 mm. less than at 8 a. m., and this increased to 0.7 or 0.8 mm. in June, but lessened to 0.4 mm. in August. During the period of active growth and greatest daily variation a trunk might show a diameter at sunrise as much as 0.9 mm. greater than at 3 p. m. the previous day.

If the data obtained from plantlets, from young trees, and trunks of mature trees be taken to apply to the corresponding parts of a large tree, a composite picture is obtained in which the growing tips and trunks are seen to be growing most rapidly at night or on foggy days, the stems 1 and 2 years old enlarge during the midday period, and the trunks shrink during this same period, indicative of a mechanism which may be of importance in the ascent of the sap.

The Growth of an Oak Trunk, by D. T. MacDougal

A dendrograph with a U-shaped yoke of bario was attached to the trunk of an oak (*Quercus agrifolia*) 35 cm. in diameter, standing near the main building of the Coastal Laboratory at Carmel, California, on February 17, 1919. The system was arranged to give an amplification of 12 and temperatures were taken by a mercurial thermometer, the bulb of which was thrust in a hole prepared for it to a position between the bark and the wood. The meteorological record was also kept.

Actual growth began on the afternoon of March 10, about a week before new leaves began to unfold on this tree, although some had been formed on other individuals of the species in the vicinity. The temperature of the trunk ranged from 9° to 14° C. Enlargement, with interruptions of a day or a few days, continued until August 5, a total period of 148 days, in which time the total increase in diameter of the trunk and bark was 6.2 mm. The bark of this oak remains alive until the trunk reaches some size and has a complete external layer upon which the contacts are made directly. The layers immediately beneath are chlorophyllose. Three large rifts formed previously in the lower part of the trunk widened irregularly, as shown by variations in the record, in which the deformations due to wind action on the crown are also discernible. Periods of retardation or cessation of growth and of shrinkage were coincident with conditions of low humidity and high temperature making for excessive water-loss.

Growth of Beech and Sycamore Trees, by D. T. MacDougal.

A dendrograph was attached to a beech tree (*Fagus grandifolia*) in the grounds of Johns Hopkins University, Homewood, Baltimore, in mid-April, under the care of Mr. W. F. Gericke. Some enlargement was discernible on May 12, immediately upon the attainment of full foliage. Enlargement continued at a low rate during the remainder of this month, June, and July. During the latter part of July the rate was especially high. Enlargement continued until about October first. The daily variation did not amount to more than 0.3 or 0.4 mm., being of the type of the live-oak at Carmel, representing the action of trunks with living bark, from which direct water-loss is much less marked than in the case of the pine and ash.

An instrument was attached to a sycamore (*Platanus occidentalis*) in the grounds of the Missouri Botanical Garden, under the care of Dr. Hermann von Schrenk and associates, in March 1918. This observation was interrupted several times and the yoke was changed to one of bario in April. When a satisfactory adjustment had been obtained on May 5, enlargement was in progress and continued through all records up to September.

METABOLISM AND NUTRITION.

The Interrelation of Photosynthesis and Respiration, by H. A. Spoehr and Frances Long.

A question on which there has always been a great deal of speculation and controversy is whether photosynthesis is a process intimately associated with the vital activity of the plant and thus dependent upon the general protoplasmic metabolism, or whether photosynthesis is an activity which proceeds more or less independently of these functions, contributing the material necessary for the release of energy and growth, but independent of metabolic activity. There is no definite experimental evidence applicable to this question, which is of prime importance in the interpretation of existing data, as well as for determining the direction of subsequent investigation. If such a direct interdependence exists, it is to be expected that factors influencing respiration would then also affect the photosynthetic activity. For this reason a comprehensive investigation of respiratory activity of leaves was also undertaken. There are, of course, a number of factors which work together to determine the rate at which carbon dioxid is emitted by the mature leaf. The most immediate of these for the present consideration is the supply of carbohydrates. As the store of carbohydrates in the leaf becomes reduced, the rate of respiratory activity exhibits a decided decrease. From such data as is available now, it may be inferred that a reduced respiratory activity represents also a lowered energy release. Were there, then, an intimate relation between the photosynthetic activity and the metabolism of a leaf, corresponding differences in the rate of carbon-dioxid fixation should appear under conditions of active and reduced respiratory activity as affected by the supply of carbohydrates.

An extensive series of experiments was inaugurated to determine the rate of photosynthesis of isolated leaves in various stages of carbohydrate depletion. These may be summarized to the effect that leaves exhibiting high respiratory activity show a correspondingly high photosynthetic activity, while leaves which are respiring at a low rate also fix carbon dioxid slowly. There are, of course, upper and lower extremes, where the rule is altered, owing to the introduction of other disturbing factors. That this is not due to the varying amounts of carbon dioxid available to the plant was established by the use of

atmospheres enriched with carbon dioxid. So far as has been investigated, this interdependence of respiration and photosynthesis applies not only in the course of activity of individual leaves, but also to the differences exhibited between different species.

From all of our experiments thus far completed, a metabolic interpretation of the phenomenon of photosynthesis seems most plausible. That is in the sense that the energy released in the processes of respiration contributes to the series of endothermal reactions involved in the synthesis of carbohydrates. The radiant energy absorbed thus would be considered as complemental in the reaction, and the whole process might be placed under that group of chemical changes designated as coupled reactions.

The most profitable conception of photo-chemical change is that which is based upon the principle of photo-electricity, and this favors the Luther theory that prerequisite to a photo-chemical reaction is the loosening of electrons. In applying the results and conceptions of photo-electricity to the process of photosynthesis it must be borne in mind that pure photo-chemical reactions have very small temperature coefficients. However, it has been known for a long time that the photosynthetic activity of a plant is very decidedly affected by temperature.

The manner in which the energy released by the respiratory actions is utilized by the plant is still entirely unknown. Probably the most noteworthy result of the energy release of respiration in plants is the formation of new compounds. These compounds may be designated as of higher energy content, although they may not again serve the plant as food material, but enter only into structural or plasmic elements of the organism. The yield of new material thus formed is indeed usually very low as compared with the total amount of material consumed in the respiratory activity. The important point, however, for the present consideration, is the fact that the breaking-down of food material, such as the relatively simple monosaccharids, yields energy in such a form and manner as to make possible these synthetic activities. Since the photosynthetic activity is greatly increased by the same agencies and conditions which augment respiratory activity, *i. e.*, by those factors which afford a greater release of energy, it would appear that such a greater release of energy favors a higher synthetic activity not only in the purely chemo-synthetic reactions of the autotrophic plants, but also those reactions involving photo-chemical changes. From the thermo-dynamic point of view it seems improbable that a synthesis of carbohydrates from carbon dioxid and water would be possible from the energy made available by the reverse process, the combustion of carbohydrates. For further information on this highly important phase of plant energetics, consideration is being given to the energy relations of those organisms which, by means of their metabolic

activities in the oxidation of hydrogen, hydrogen sulphide, methane, etc., liberate relatively enormous quantities of energy and are thus capable of fixing the carbon dioxid of the atmosphere without the action of radiant energy.

Carbohydrate Supply and Respiration, by H. A. Spoehr.

Prerequisite to a rational study of the effect of various conditions on the respiratory activity of leaves is more precise knowledge of the nature of the normal course of respiration. This information is, of course, also essential in application to the study of photosynthesis, as has been already indicated. An extensive series of experiments planned to determine the rate of carbon-dioxid emission was carried out by the use of leaves cut from the plant and seedlings growing in various nutrient solutions. A mercury-seal respiration chamber has been devised which greatly facilitates working with various plants at constant temperatures.

When a leaf with an abundant supply of carbohydrates is kept in the dark at constant temperatures, *e. g.*, 24°, the rate of carbon-dioxid emission falls steadily as the carbohydrate-content diminishes.

If a leaf, the carbohydrate-content of which is almost exhausted, is placed with the petiole in a 5 to 10 per cent dextrose solution, the carbohydrate-content of the leaf again rises. The carbon-dioxid emission, however, does not show a corresponding increase with the augmented sugar-supply, but increases a little and then continues to fall. Experiments have been directed to determine the conditions or substances necessary for regaining or maintaining the original higher rate of respiration.

The possible influence of various mineral nutrients was tried out by studying the effect of a series of solutions prepared on the basis of Shive's investigations. The effect of three components was tested—nitrate, potassium, and magnesium. At the present stage of the investigation it seems doubtful whether any definite information regarding the rôle of mineral nutrients in respiration can be gained from these experiments.

Other experiments were directed toward increasing the amount of protein in the leaves. With nitrates supplied, and when the nutrient solution contains 10 per cent dextrose, the leaves are capable of synthesizing proteins in the dark. Under such conditions the reduced rate of respiration was somewhat increased, but also only slightly. The most promising results were obtained with combinations of monosaccharides and amino-acids in the nutrient solution. It is, however, still an open question in what manner these combinations operate; that is, whether they directly influence enzyme action or in such a manner as to produce favorable conditions of solution (*e. g.*, the hydrogen-ion concentration) within the protoplasmic complex.

Nutritive Value of Food Reserve in Cotyledons, by B. M. Duggar.

Few if any quantitative studies have been made to measure the importance and rôle of the cotyledons or seed-leaves in the nutrition of the seedling and young plant during germination and later. In the case of such seed as the pea or bean, where the cotyledons constitute the entire food reserve, the common assumption is probably to the effect that the seed-leaves are important during the first few days of germination, or until the first green leaves are developed.

It had seemed possible that problems of considerable interest might be approached through a critical study of the food reserves, and preliminary tests had been made with a few seeds, especially Canada field peas. The latter were germinated over tap-water until the plumules were well established, and the seedlings were then used in arranging the usual solution cultures. As soon as the young shoots exhibited considerable chlorophyll development, the seed-leaves were cut away in duplicate cultures containing 10 plants each, while in another lot the seed-leaves were left intact. To both lots of cultures were added standard nutrient solutions containing all necessary ions, including a favorable concentration of nitrate. A marked contrast in growth was evident after the second day, and after 2 weeks the normal seedlings were twice as tall and far more vigorous than those lacking cotyledons. Although provided with many green leaves capable of photosynthetic activity, and with an adequate supply of nitrate in the substratum, the seedlings without cotyledons were greatly checked in development, and at the close of the experiment it seemed doubtful if they would attain maturity.

During the summer of 1919 a more careful study has been made of the effects of excising cotyledons after various time intervals up to 10 days after germination, or until the leafy shoot is 4 to 6 cm. in height. At the same time, attempts have been made to substitute for the loss of the cotyledons by adding singly to the nutrient salt solution glycocoll, alanine, sodium asparaginate, urea, nucleic acid, and sodium nucleinate. The best results were obtained when these substances were used at considerable dilution, M/100 for the simpler compounds and 0.1 per cent for nucleic acid and sodium nucleinate.

The data clearly indicate that a nutrient substitute for the cotyledons has not been found. Sodium nucleinate has increased more than any other compound, the growth amounts in the cultures lacking cotyledons; yet the growth (green weight) of the normal seedlings in salt solution alone exceeded in every case the growth in the cultures containing organic compounds but with seed leaves excised. Removal of the cotyledons after the plants are 5 cm. or more in height has relatively little effect. It is recognized that pure cultures must be employed in further work in order to eliminate bacterial action.

At present the failure to substitute for the cotyledons may be explained by one or more possibilities, among which are the following: (1) that penetration of organic substances may be difficult; (2) that a combination of various organic nutrients may be essential; or (3) that the cotyledon contains an essential "vitamine."

Some Factors in the Salt Requirements of Plants, by B. M. Duggar.

As a result of studies previously reported, the writer has drawn attention to the necessity of taking into consideration the hydrogen-ion concentration of the salt solution furnished such plants as wheat, corn, and peas. When phosphate is furnished as the monobasic salt of potassium, and when the other salts employed yield solutions which are neutral or nearly so, the pH of the mixed salt solution may not be far from the limit of acidity which the plants mentioned will tolerate without experiencing a marked diminution in growth. Unfortunately, the acid salts are not constant in pH unless carefully recrystallized, and the variations encountered may be within either the optimal or supra-optimal range. Moreover, the effects of conditions of growth must be taken into consideration. It has been shown, for example, that high temperature and low humidity (high evaporation) are directly or indirectly related to increased acid injury.

The favorable range of conditions for the growth of wheat afforded by the climate of the Coastal Laboratory (Carmel, California) offered an excellent opportunity to investigate further some of the factors determining the maximum healthy growth of this plant. The usual solution cultures were employed and all experiments were made with a variety of wheat particularly suited to the conditions, namely, the Pacific Bluestem, seeds of which were obtained from the Introduction Garden of the U. S. Department of Agriculture at Chico, California. The cultures were arranged in glass beakers exposed on a lattice table in the open, and weighings of the plants were taken after a period of 28 days. Ten plants were included in each culture.

In an important series completed during July and August 1919, special attention has been directed to a determination of the most favorable proportions of the salts in a solution consisting of potassium nitrate, magnesium sulphate, calcium sulphate, and "soluble ferric phosphate," previous work having indicated special merit in such a combination of salts. In 21 cultures the compounds mentioned have been variously combined in concentrations ranging from a minimum up to four times this amount. In addition to varying the concentrations of these salts, aluminium compounds have been added in certain cases in the form either of aluminium hydroxide or postassium aluminium silicate. In this particular group of cultures the range of hydrogen-ion concentration has not been considerable, the maximum and minimum pH values being 6.6 to 7.4. In all of these cultures there has

gradually developed a precipitate in the form of a suspension, consisting in part of the iron salt, but in no case has this proved disadvantageous in the conduct of the experiments.

In general, this series of cultures has exhibited remarkable vigor and an intensity of green which contrasts strongly with the other cultures made at the same time, in which the concentration of iron is much less. Maximum growth occurred in those cultures in which the partial volume-molecular concentration of the salts was as follows: KNO_3, 0.0099; $CaSO_4$, 0.00155; $MgSO_4$, 0.00115; and soluble ferric phosphate 0.25 gm. per 1,000 c.c. This represents the maximum concentration of all salts employed, but at the same time it represents in all probability approximately the most favorable concentrations in which these salts may be used, inasmuch as previous work under conditions of high evaporation had indicated a falling off in the growth-rate when concentrations above this were employed.

The next more favorable group of results are those in which the iron salt and the magnesium are reduced to one-half concentration, the calcium and potassium remaining at maximum. A slight increase in magnesium with diminution in the amount of calcium has invariably resulted in a much lower growth-rate. In these experiments there has been no notable increase in the growth quantity as a result of the addition of aluminium, and it is quite probable that this is related to the fact that in no culture is the amount of iron as low as in the usual salt solutions recommended for the growth of wheat.

A second group of experiments has included a solution of iron, magnesium, and potassium salts as mentioned above, in minimum quantities, with calcium supplied as monobasic calcium phosphate. In this case, however, the growth quantities are as low as the minimum of the preceding group, and increasing the magnesium and potassium salt to a maximum quantity has afforded little additional growth increase.

Comparisons have been made between the solution first discussed and one consisting of monobasic calcium phosphate, potassium nitrate, and magnesium sulphate, with the addition of iron either as the sulphate or as the soluble ferric phosphate, in both cases supplied in the amount usually recommended, namely, 0.0044 gram per liter of solution. Such solutions have yielded growth quantities comparable only with the poorest cultures in the group first discussed.

Elaborate experiments are now in progress to determine the influence of various proportions of iron in the form of the soluble ferric phosphate contrasted with the insoluble ferric phosphate in solutions consisting of (1) monobasic potassium phosphate, calcium nitrate, and magnesium sulphate; (2) monobasic calcium phosphate, potassium nitrate, and magnesium sulphate; (3) calcium sulphate, potassium nitrate, and magnesium sulphate (the phosphate in this case being supplied only in the form of the iron salt).

Refinements in the Indicator Method of Hydrogen-ion Determination, by B. M. Duggar.

The inherent complexity of the hydrogen electrode, or gas-chain method, of determining hydrogen-ion concentration, and the care requisite for the maintenance of the apparatus in standardized condition, are some of the factors which operate against the general applicability of this method in most biological laboratories. Further than this, there appear to be relatively few data bearing upon the possible errors or complications arising from the use of the gas-chain method with complex biological fluids of unknown composition.

In biological work, moreover, a proximate determination promptly made at any moment with a relatively small volume of fluid may be far more important than a delayed precise determination, accurate to the second decimal of the pH exponent. With the relatively stable and easily prepared thallate and phosphate standard solutions, likewise with the newer thymol, phenol, cresol, and other indicators, which have recently been developed through the work of Clark and Lubs, the determination of the pH of colorless solutions is readily and accurately carried out.

The chief difficulty with the indicator method as applied to plant juices, decoctions, etc., has been the factor of color or pigment in the sample. Simple comparators, whereby "shield" solutions have been employed in test-tubes, have been unsatisfactory in compensating for the color of the sample. It has been shown in an earlier paper that practically all difficulties are removed by the adaptation of certain types of colorimeters in this work, and the development of the method has been pursued during the summer of 1919.

The microcolorimeter of Duboscq has proved admirable for this work, both because of its form, the solidity of the cups, and the fact that it may be employed, where necessary, when the total volume of solution available does not exceed 2 c.c.

The usual method of employing a colorimeter is of course that of comparing the sample colored solution in one cup with a standard solution in the other cup, the latter corresponding to a known quantity of the substance for which the test is made. The cups are raised or lowered by the adjustment screws until a match is obtained, and the depths of the columns are then inversely proportional to the concentration, so that the value of the sample is determined in terms of the standard.

In determining the hydrogen-ion concentration of pigmented fluids or juices, the colorimeter has two essential functions: (1) the convenient use of shield solutions, thus compensating with the least possible optical difficulty for the native color of the sample, and (2) affording an accurate means of determining in which standard solution (of known pH) the color-change of the indicator corresponds with

that of the sample containing the same indicator, both being examined at an arbitrary but equal depth, the latter also being made equal to the depth of the shield solutions employed.

The use of shield solutions necessitates employing a colorimeter with hollow cylindrical plungers which screw off conveniently. If (*a*) denotes the right-hand plunger and cup and (*b*) the corresponding left-hand parts, the following procedure is recommended: The shield solutions are (*A*) the pigmented sample and (*B*) distilled water. As neither of these is changed during an examination of any particular sample, even though different indicators are employed, a measured quantity of (*A*) is placed in plunger (*a*), and the same quantity of distilled water in plunger (*b*). The amounts to be used should be inversely related to the intensity of color in the sample, and the depth of the column is calculated after determining the capacity of the plunger-tube and its length, since the quantity introduced is also known, thus furnishing three known quantities in the proportion.

Into the colorimeter cup (*b*) is then placed the sample plus indicator, and into cup (*a*) that standard solution (plus indicator) which may seem more or less to correspond in color. The cups are then set by means of the thumb-screws at a depth corresponding to that of the shield solutions employed, and examination is made. It is convenient to arrange a series of serological test-tubes, each with 2 to 5 c.c. of the standard solutions plus indicator, a series for each indicator, differing in value by one-tenth or two-tenths of one unit of the exponential scale. The standard solution in cup (*a*) is of course changed if the color does not match, and trial is made until there is exact agreement.

In the microcolorimeter of Duboscq employed, the plunger-tube is usually half-filled with the shield solution, corresponding to 0.625 c.c., and to a depth of 16.5 mm. The amounts of the solutions placed in the cups is immaterial, so long as the plunger touches the liquid, inasmuch as the depth of column examined must be set to correspond with the shield. Moreover, the form of the cup is such that the expanded upper part holds any surplus liquid forced out of place by the plunger. The red indicators (red-yellow or yellow-red) have been particularly serviceable, and with the colorimeter the full value of the entire range of the indicator change may be realized. Where indicators overlap in pH the choice would be of the one contrasting best with the sample.

Soil Aeration Experiments with Helium, by W. A. Cannon and E. E. Free.

In previous experiments on soil aeration,[1] nitrogen has been used as an inert gas to replace the normal atmosphere of the soil. This pro-

[1] Cannon, W. A. Carnegie Inst. Wash. Year Book for 1915, pp. 63–64; Year Book for 1916, pp. 74–75; Year Book for 1918, pp. 81–83.
Free, E. E., and B. E. Livingston. Year Book for 1915, pp. 60–61.
Livingston, B. E., and E. E. Free. Year Book for 1916, p. 78.
Cannon, W. A. Amer. Jour. Bot., vol. 2, pp. 211–224 (1915).
Cannon, W. A., and E. E. Free. Science (n. s.), vol. 45, pp. 178–180 (1917).

cedure is open to the objection that nitrogen is known to react with numerous other substances and with certain living organisms, this suggesting a possibility that soil atmospheres of nitrogen may not be entirely inert as regards plant roots, soil bacteria, and other living elements of the soil. The recent development of processes for the procurement of helium, and the cooperation of the Bureau of Steam Engineering of the U. S. Navy in supplying a quantity of this gas, have made it possible to repeat previous experiments, using helium instead of nitrogen. Because of its absolute inertness chemically, it is highly improbable that this gas could have any specific or direct effect on any constituent of the soil. Preliminary tests with mixtures of the helium and air have shown the gas used to be free of any impurity harmful to ordinary plants.

Experiments on the garden sweet pea have been made, using the technique previously described by Cannon, in which the seedlings are grown in sand wetted with nutrient solution in glass tubes at constant temperatures and the rate of root-growth has been observed directly. Three tubes were used. In one the normal soil-atmosphere was replaced by nitrogen; in the second, helium was used instead of nitrogen; in the third, a slow stream of helium was maintained through the tube. In the tubes containing static atmospheres of helium and nitrogen respectively, root-growth stopped at once. In the tube with the stream of helium, root-growth continued at a rate not greatly, if at all, below the normal growth in air. After three days air was again supplied to the roots. In all cases root-growth recommenced, but in the case of the plant exposed to nitrogen the main root did not grow, although the laterals did. In the other cases (after helium) both the main roots and the laterals grew.

Experiments with the ordinary potato were made according to the technique described by Livingston and Free, in which the plant-roots and the soil in which they grow are sealed into an air-tight tin can, the plant-stem passing through the seal. On repeated experiments with potato plants, both with and without tubers, the injury to the plant is evident substantially sooner when the normal soil-atmosphere is replaced by nitrogen than when helium is used. Examination of the roots shows the injury to consist in a softening and decay of all protoplasmic and storage tissues, in which the tuber, when present, is also involved. This decay is similar in character in cultures with nitrogen and helium, but progresses more rapidly in the former gas.

A comparative series of cultures, in which the carbon dioxid produced in the soil was measured, led to results summarized in the following table. Six cultures were included; two had potato plants with tubers, two had plants without tubers, and two had soil only. In one of each sort the soil-atmosphere was replaced by helium, in the other

by nitrogen. The soil was the same in all cases and the plants used were selected for similar age, size, and condition. Approximately 700 grams of soil were used in each case and the figures are in cubic centimeters of carbon dioxid produced per 24 hours, these figures being reduced to the basis of 0° C. and 760 mm. pressure.

	CO_2 produced per 24 hours.	
	With nitrogen.	With helium.
	c.c.	c.c.
Soil only	13.0	12.5
Potato plant without tuber	15.7	11.1
Potato plant with tuber	42.6	28.4

The interesting feature of these results is the fact that when the plant is present the production of carbon dioxid is greater in nitrogen than in helium. The greater production of carbon dioxid from the cultures containing tubers is obviously due to the much larger amount of material suffering decay. While the quantitative precision of the results given leaves much to be desired, and while the necessity of numerous and careful repetitions is fully appreciated, it is believed that the higher production of carbon dioxid in the nitrogen atmospheres is a fact. It will be noted that this agrees with the visual observation of more rapid root and tuber decay in nitrogen than in helium, and also with the fact that the main root of the sweet pea did not recover from nitrogen treatment but did from helium treatment.

Interpretation of these results will not be attempted at present, but it may be suggested that the results are consistent either with (1) a stimulating effect of nitrogen on the bacterial actions which may be assumed to be responsible (whether primarily or secondarily) for the observed root decay, or with (2) a depressing effect of the helium on this bacterial action. A stimulating effect of nitrogen is not unthinkable in the light of the known existence of nitrogen-utilizing anaerobes. A depressing effect of helium, if real, would presumably be due to some impurity active against the anaerobes, but not against the aerobes. A specific effect of helium is extremely unlikely, and, as noted, the helium has been tested for deleterious impurities, of course under aerobic conditions.

ECOLOGY.

The Vegetation of a Desert Valley, by Forrest Shreve.

The work on the vegetation and soils of the Avra Valley, which was begun in 1918, has been continued. The mapping of the general types of vegetation has been extended over a larger area, with a view to ultimately extending it over the whole drainage basin. The character

of the soils has been mapped over a small portion of the valley in which the vegetation has been charted in detail, and is being extended to the entire floor of the valley. A series of photographic records has been begun for certain areas in which erosion is active, and benchmarks have been established from which to secure future measurements of the changes of level to which the floor of the valley is subjected. It is desired particularly to study the deposition and cutting of the incipient streamways, the development of which is retarded by their very slight gradient and by their heavy load of detrital material. Photographs are also being secured as records of the changes of vegetation due to the deposition on portions of the valley floor and the inundations to which it is seasonally subjected.

A Soil-Temperature Survey of the United States and Canada, by Forrest Shreve.

The preliminary soil-temperature survey of the United States and Canada, which was begun in 1916 as a committee project of the Ecological Society of America, has been continued during the past year, through the reappointment of a committee consisting of Forrest Shreve, chairman, and Dr. Alfred E. Cameron, of the Dominion Entomological Service of Canada.

In the United States 3 new stations have been added to the 30 in operation during 1917, and observations have been begun at the Dominion Experimental Farms in Canada. The location of the new stations is such as to fill some of the largest gaps in the geographical distribution of the older series. Readings at two stations in the Western States have unfortunately been discontinued on account of the curtailment of work at certain of the experiment stations of the Forest Service.

Special features of soil-temperature work have also been continued by five of the cooperators, giving readings at different depths, and data regarding the influence exerted on the temperature of the soil by its physical character, by the nature of the cover, and by tillage of surface. The complete elaboration of the results of the survey is being deferred until the completion of the third year of continuous observations.

Stem Analysis and Elongation of Shoots in the Monterey Pine, by Forrest Shreve.

The Monterey pine (*Pinus radiata*) is of local occurrence along the coast of central California and is strictly confined to the maritime climate of the "fog-belt." The equable conditions of temperature in this belt give the pine a frostless season varying from 8 to 10 months in length. The rapid growth of the Monterey pine has frequently been noted, but no exact work has been done with it, chiefly owing to its limited occurrence and negligible commercial value.

During the summer of 1919 advantage was taken of several small cuttings that had been made for carrying out a stem analysis of this tree. When ages are plotted against diameters a straight-line curve is secured up to the age of 80 years, beyond which extremely few of the trees survive. An average diameter (inside the bark) of 33 cm. (13.2 in.) is attained at the age of 30 years and of 57 cm. (22.8 in.) at the age of 60 years. Some of the most rapidly growing individuals showed a diameter (outside bark) of 58 cm. (23.2 in.) at 28 years and 98 cm. (38.3 in.) at 60 years.

On the stump of each tree measurements were made of the growth by decades. The increase in diameter is greatest between the ages of 10 and 20 years, but the actual wood increment increases up to 80 years, at which age the stump has an average area of 3,155 sq. cm. (489 sq. in.). The greatest observed diameter growth was in a tree 113 cm. (45 in.) in diameter which was felled at the age of 84 years and showed for its second decade an increase of 35 cm. (14 in.) in diameter.

The Monterey pine is found both on the sandy soil of old stabilized dunes and on a gravelly clay. The stem analyses were made on trees which were nearly equally divided between sites with the two types of soil. On plotting ages against diameters there is no discoverable difference of growth-rate on the two soils.

The elongation of the shoots commences at an early date in the spring and continues at a slightly decreasing rate until September. Vigorous young trees measured at monthly intervals showed on March 30 a growth which proved to be an average of 38 per cent of the total growth in height for the year. In a series of 350 young trees the percentage of 1919 growth to previous height-growth was found to range from 86 per cent for seedlings 10 to 20 inches in height down to 14 per cent for saplings 200 inches in height. In exceptional cases the young seedlings 10 to 20 inches in height grew 160 per cent of their previous height in the season of 1919. Particularly favorable conditions sometimes result in a height-growth of as much as 10 feet in one year in trees 12 to 15 feet in height, and even greater growth has been reported.

Unlike other pines, this species commonly forms one or two whorls of branches on the shoots which are not yet one year old. The height-growth of previous years can not, therefore, be determined from the length of the intervals between whorls of branches.

A comparison of height-growth with diameter-growth for the last 4 to 7 years in a number of saplings 12 to 15 feet high showed no definite correlation, either positive or negative, between these phases of growth. Exceptionally active height-growth appears to be constantly correlated with a small growth in diameter. The individual conditions of crown development must be taken into account in a more exact analysis of this correlation.

Plant Habits and Habitats in the More Arid Portions of South Australia, by W. A. Cannon.

The following are some of the more important conclusions and results derived from a field study of the vegetation in central, northern, and southwestern South Australia in 1918.

An important feature of the physical environment of the State is the amount and character of the rainfall. Over the northern portion, consisting approximately of 75 per cent of the land area, the total precipitation is 10 inches or less. Much of this region is the great artesian basin of central Australia and is partly below sea-level. An area estimated at 3 per cent or more, lying wholly within this basin, receives 5 inches or less of rain annually. It is proposed to term regions of South Australia which have a rainfall of 5 inches or less each year desertic or eremaic, and regions with an annual precipitation between 5 and 10 inches as arid. Where the rainfall is between 10 and 15 inches the regions will be referred to as semiarid or subarid.

The rainfall of South Australia is periodic. About 76 per cent falls in the cool season, the largest proportion of which occurs in the southern half of the State. The monsoonal rains of summer are of importance in the Far North, where, however, neither the cyclonic winter rains or the summer monsoons are dependable. Since the rainfall is periodic, the rainless periods are also regular in their occurrence and are of undoubted importance in shaping the leading features of the perennial vegetation. In arid South Australia the number of rainless days each year is 300 or over, and that in the semiarid regions is about the same, while in the eremaic districts it may exceed 340.

A marked feature of the rainfall is the number of storms in which the precipitation totals 0.15 inch or less, and this is a characteristic most marked in the driest regions. At Oodnadatta, for example, where the rainfall averages 4.68 inches annually, about 31.2 per cent of the entire precipitation occurs in such small amounts. In one year as much as 56 per cent of the entire rainfall at Oodnadatta was received in storms of this kind. Where rain occurs in no greater amount than 0.15 inch, or even more than this, it does not moisten the soil to a depth useful for roots, and the configuration of the surface of the soil of itself is, under such conditions, of no moment. The effective rainfall in the desert, therefore, is considerably under that presented in official summaries.

South Australia has a mild temperate climate, with hot summers, especially in the north, and cool winters. In the far north (William's Creek) a maximum shade temperature of 119.1° F. has been recorded. The daily variation in temperature may be 40° F. or more. The shade temperatures of the far north reach or exceed 90° F. for about one-third of the year. In approximately 64 per cent of the state, in a

territory corresponding roughly to but somewhat less than the eremaic and arid regions, the mean annual temperature is 65° to 75° F.

In the far north the yearly evaporation is 100 inches or more. In the arid southwestern portion (Eucla) it is 95.98 inches. At Adelaide, annual rainfall 20.95 inches, the yearly evaporation is 54.9 inches.

The perennial vegetation of the drier portions of South Australia is thus subject to high temperatures for a portion of the year, high evaporation rates, a large number of days each year which are rainless, and a relatively or actually low rainfall. In addition to these may be mentioned intense insolation concerning which there are no available data. Particular adjustments to the environment of the flora as a whole and in certain details may be given in part as follows: In the desert regions trees are confined to the water-courses, except such as occur in the sandhills. In either case they are relatively small. Shrubs are not numerous away from the water-courses, although they occur sparingly in relatively dry situations on the high plains. On areas which in the eremaic and arid regions are extensive, and where the surface drainage is poor or wanting, halophytic shrubs are numerous both as to species and individuals. It is probable, however, that in the desert regions perennials in any situation are not sufficiently numerous to prevent erosion by water or by wind.

In the arid and subarid regions the trees and shrubs stray away from the water-courses, so that in places open forests, as to trees, or open pigmy forests, as to shrubs, are formed. The number of species as well as of individuals is also greater. There is also a striking increase in the transpiring surface of perennials. While such vegetational features are closely related to the amount of the yearly rainfall, this is not invariably the case. For example, in the southwestern portion of the state, Ooldea, there is an extensive region of sandhills where the annual precipitation is less than 10 inches, but where it is so well conserved that the vegetation is more abundant than might be expected from the amount of precipitation.

The characteristic trees of the desert region (Oodnadatta) are mainly *Eucalyptus* spp. and *Acacia* spp. Species of *Eremophila* are the most striking shrubs of this region.

In the arid region (Copley, Tarcoola, Ooldea, Port Augusta) the number of trees and shrubs is very considerable and includes among others the following genera: *Acacia, Callitris, Cassia, Casuarina, Dodonæa, Eucalyptus, Fusanus, Gravillea, Hakea, Heterodendron, Leptospermum, Melaleuca, Myoporum, Petalostylis*, and *Zygophyllum.*

In the subarid regions (Quorn, Blanchtown, etc.) the number of species of trees and shrubs is very considerable and need not be mentioned further.

The halophytic vegetation is a characteristic feature of the arid and desert regions. More than 50 species occur in the region east of Lake

Torrens. The abundance of halophytes makes possible the very considerable pastoral industry of the far north.

A list of particular adjustments of the species to the environment would include, among others, the following: The leaf-surface is usually greatly reduced and aphyllous species are common. In the acacias and in certain cassias the true leaves may be replaced by phyllodia. The leaves may be heavily cuticularized and often they are coated with resinous substances, especially when young. In many instances leaves and young stems are covered with trichomes, although such covering is not a striking character of the species as a whole. Water-storage capacity is present in the roots of certain species, as *Gravillea stenobotrya* and *Eucalyptus* sp. In subarid regions species of *Eucalyptus* with shrub habit, the "mallee," have shortened stems which are important water-storage organs. Succulence among non-halophytic perennials is wanting or rare. The superficial roots of several species are especially well developed and point to a response on the part of the species to relatively light rains. In the sandhills and along water-courses the superficial roots may attain great length. Where water-storage capacity is present in roots it is usually situated in, if not confined to, such as are superficially placed. Many small trees have canopy-formed shoots. This is a striking character of species of "mallee," but occurs in species of other genera as well. Vegetative habit of reproduction through stolon-like subterranean organs is frequently met in shrubs and trees.

Reactions of Roots of Species with Dissimilar Habitats to Different Amounts of Carbon Dioxid in the Soil, by W. A. Cannon.

It has previously been reported[1] that the roots of seedling *Prosopis velutina* and of cuttings of *Opuntia versicolor* exhibit an unlike reaction, as shown by a modification of the rate of growth of the roots, to an excess of carbon dioxid in the atmosphere of the soil. In the case of *Prosopis*, whose roots may penetrate deeply, a relatively great tolerance to carbon dioxid is shown. But as regards *Opuntia*, with superficially placed roots, the tolerance is not so marked. The difference between the two species in the root-carbon-dioxid relation, however, is not supposed to be of definitive importance in the economy of either species. The reactions of roots in relation to carbon dioxid of the atmosphere of the soil of two additional Arizona species, which occur under natural conditions somewhat similar to those of the two species above referred to, and of a third species whose habit of growth and whose habitat are widely different, are described below.

The plants in question are *Covillea tridentata* and *Krameria canescens*, from southern Arizona, and *Mesembryanthemum* sp. from the neighborhood of the Coastal Laboratory, Carmel, California. So far as the habit

[1] Carnegie Inst. Wash. Year Book for 1916, p. 74.

of growth and the character of the roots are concerned, which have been published in various studies, it need only be said here that *Covillea* is a sclerophyllous shrub, without water-storage capacity, which occurs in relatively shallow and fairly light soils, with relatively shallowly placed roots, but which also grows along water-courses where the soil is deep and sandy. Under such conditions the roots may penetrate to a depth of 2 meters, or possibly more. *Krameria* is a root parasite, with *Covillea*, among other perennials, as one of its hosts. It bears leaves which are deciduous and the root system is relatively shallow, apparently under any conditions. It is also without water-storage capacity. *Mesembryanthemum* is a succulent with shallow roots, generally growing in sandy soil.

In the experiments on the root-carbon-dioxid relations the roots of the three species were treated in a similar manner. They were grown in glass tubes which were filled with fairly coarse sand and which were kept in thermostats in which the temperature of the soil varied scarcely if any more than 2° C. The shoots projected into the air and were subject to daily fluctuation in temperature amounting to about 5° C. Artificial atmospheres were employed which consisted of 25, 50, and 75 per cent carbon dioxid, the balance being atmospheric air. This was used to replace the normal soil-atmosphere, and at the end of the experiments it in turn was replaced by atmospheric air. The leading results of the experiments can be briefly given. In the case of *Krameria*, carbon dioxid in any percentage exercised a depressing effect on the rate of growth of the roots, and, in fact, growth of the roots ceased after a time, which was longer or shorter in accordance with the duration of the exposure to the gaseous mixture as well as with the percentage of carbon dioxid used, but after the admission of atmospheric air, the growth of the roots was resumed. In a soil-atmosphere containing 75 per cent carbon dioxid it was observed in *Krameria* that the effects were less harmful at soil temperatures which were approximately optimal than it was at temperatures of the soil which were about 10° C. above this, or in other words, that about optimal for root-growth of its hosts. In *Covillea*, carbon dioxid of whatever concentration used was disastrously harmful. The growth of the roots was quickly retarded and soon ceased. In case of recovery upon the admission of atmospheric air it was seen to occur many hours subsequent to the employment of the artificial soil-atmosphere containing the high percentages of carbon dioxid. As to *Mesembryanthemum*, the effects following the use of soil-atmospheres containing large amounts of carbon dioxid, in certain respects, were different from the effects observed in the other species treated. In *Mesembryanthemum* the rate of growth of the roots is decreased in atmospheres containing 25 to 75 per cent carbon dioxid, and finally, after relatively long exposures to the higher concentrations, it ceases. However, it was seen to be renewed relatively soon upon the replacement by

atmospheric air of a soil-atmosphere rich in carbon dioxid. The following table summarizes two representative experiments with *Mesembryanthemum* and illustrates the points:

TABLE 1.—*Growth of roots of Mesembryanthemum sp. in a soil atmosphere.*

	1	2	3	4	Remarks.
Growth of roots of Mesembryanthemum sp. in a soil atmosphere containing:	*mm.*	*mm.*	*mm.*	*mm.*	Observational periods of 2 hours each. The artificial soil-atmosphere was administered the first two periods, when it was replaced by atmospheric air.
25 p. ct. carbon dioxid......	1.3	1 4	0.4	1.6	
75 p. ct. carbon dioxid......	1.5	0	0.2	0.5	

In comparing the effects of the different percentages of carbon dioxid on the three species, especially as regards the length of time required in each case to bring about cessation of growth of the roots, the results, although not altogether consistent in every instance, are quite in harmony as a whole with the conclusions just presented. When a gaseous mixture is used which contains 25 per cent carbon dioxid about 1.5 hours pass before growth of the roots entirely ceases in *Covillea,* 2.5 in *Krameria,* and over 4 hours in *Mesembryanthemum.* In a 75 per cent mixture, growth of the roots ceases at once in *Covillea.* In *Krameria,* with the roots in a soil-atmosphere of this high carbon-dioxid concentration at super-optimal soil temperatures, as above noted, the growth of the roots may continue for 1.25 hours, but at lower, optimal, temperatures of the soil the growth of the roots continues for a longer time than this. In *Mesembryanthemum,* however, an exposure of over 2 hours to a soil-atmosphere containing 75 per cent carbon dioxid is apparently necessary, soil temperatures being most favorable for root-growth, before growth of the roots ceases.

In these experiments the amount of oxygen available for the roots rapidly decreased with the increase in the amount of carbon dioxid in the artificial soil-atmospheres used, so that to the specific effects of carbon dioxid must be added the effects following partial deprivation of oxygen, which, especially in the case of high percentages of carbon dioxid, is an important factor. However, it is clear that in the case of *Mesembryanthemum* the roots are only slightly affected by the excess of the one or by a deficit of the other. It is probable that aeration of the roots of *Mesembryanthemum* is not a factor of the first importance in this species as it is in *Covillea* and *Krameria.*

Size and Form of Leaves in Desert Plants, by W. A. Cannon.

The well-known tendency of xerophytic perennials to have relatively long leaves finds its ultimate expression in the vegetation of extremely dry regions. A preliminary survey of the leaves of desertic and arid

South Australia establishes this as a well-marked condition. Moreover, the feature referred to is not necessarily correlated with an especially small leaf-area. For example, a representative leaf of *Heterodendron oleæfolium* is 110 mm. in length by 14 mm. in width and has an area, one side only, of 1,080 sq. mm. The phyllodia of *Acacia stenophylla*, and which may be regarded as leaves, may be 375 mm. in length and only 5 mm. wide, with a surface area, one side, measuring 1,700 sq. mm. A "composite" leaf constructed by averaging the

Leaf measurements of eremaic and arid perennials of South Australia.

Species	Length.	Width.	Area.
	mm.	*mm.*	*sq. mm.*
Acacia aneura[1] (broad form)	57	8	350
aneura (narrow form)	55	2.5	100
brachystachya	100	1.5	140
calamifolia	67	1	65
cambadgei	20	8	140
colletioides	12	1	12
iteaphylla	88	5	350
kempeana	64	7	410
linophylla	140	1.5	210
oswaldii	47	4	175
pycnantha	110	26	1,050
randelliana	70	2	130
rigens	85	1.5	120
salicina	75	5	350
sentis	31	3.5	100
stenophylla	375	5	1,700
tarculiensis	34	10	300
tetragonophylla	30	1	30
Dodonæa attenuata	85	3	200
Eremophila alternifolia	34	2	30
brownii	26	4	110
freelingii	55	7	230
latrobei	32	1.5	32
longifolia	80	5	230
neglecta	46	5	190
paisleyi	28	2	50
Eucalyptus incarnata var. dumosa	87	18	1,280
odorata	75	10	650
oleosa	86	18	1,000
leucoxylon var. macrocarpa	90	25	1,400
Fusanus acuminatus	72	7	300
spicatus	47	10	290
Geigera parviflora	47	3.5	160
Gravillea stenobotrya	135	1.5	190
Hakea leucoptera	72	2	140
multilineata	210	6	1,200
Heterodendron oleæfolium	110	14	1,080
Jasminum lineare	96	5	450
Leptospermum lævigatum var. ninus	26	5	95
Melaleuca glomerata	20	1	18
paroifolia	9	1	7
uncinata	25	1	22
Myoporum platycarpum	67	7	450
Olearia muelleri	90	6	25
Pholidia scoparia	20	1	18

[1] Phyllodia.

length and breadth of 30 species, not including *Acacia*, has a length of 64 mm. and a width of 5 mm. A similar leaf built on the measurements of 16 species of *Acacia* is 84 mm. long and 3.5 mm. wide. Results derived from constructing ratios based on the relation between area, one side, and length further illustrate the point. In the case of circular leaves this ratio is approximately 1:54.3, and in linear leaves it is nearly 1:1. In the largest leaf-size class for "microphylls" of Raunkiaer the ratio is approximately 1:23.6. The ratio of leaf-area to leaf-length for 29 species of desert and arid perennials from South Australia is 1:4.7. So far as these dry regions are concerned, there are relatively few species having the least ratio, and these do not necessarily live in the driest habitats, although the ratio for such species is necessarily low.

Ecology of the Strand Vegetation of the Pacific Coast of North America, by William S. Cooper.

The sand-dunes and beaches are the principal field of study, but cliffs, bluffs, and salt marshes are incidentally involved. The special value of the study with regard to development of the fundamental laws of the science of ecology lies in the fact that the initial soils of beach and sand-dune are everywhere extremely similar, if not almost identical, and that any striking vegetational differences must be correlated with climatic factors. There is here, therefore, an excellent opportunity to investigate the effects of climatic control upon distribution, ecological character (form, structure, function), and successional development.

The general method used is a combination of extended exploration and thorough study of carefully selected localities. The latter phase must include (1) measurement of habitat factors; (2) investigation of plant form and structure (root system, conductive system, leaf); (3) determination of the courses of the successions leading to the climax in each region, involving the establishment of permanent quadrats and transects; (4) experimental greenhouse work to check the observational results wherever possible.

The month of May was spent in a careful study of the strand vegetation from the Coronado Hotel to the Tia Juana River, a stretch of 16 kilometers. Vegetational development proceeds along two lines. In the first, beginning in fresh-blown sand, *Abronia maritima* is the principal pioneer. This plant, because of a persistent negatively geotropic tendency in the branches, coupled with scanty development of mechanical tissue, builds dunes which increase rapidly in height so long as the accumulating sand supports the shoots in their erect position. When, because of increase in height of the dune or from any other cause, the upward building slackens, the weight of the shoots

overcomes their tendency to grow erect and they trail over the surface, producing numerous branches which repeat the process, soon forming a mat which is the first step in the fixation of the dune. *Franseria bipinnatifida* is also an important pioneer, but its branches are diageotropic from the first, and it therefore stabilizes flat surfaces instead of first building hillocks. The second stage includes a number of semi-pioneers, the most important being *Mesembryanthemum æquilaterale, Abronia umbellata, Convolvulus soldanella, Nemacaulis denudata, Croton californicum,* all trailing or decumbent plants which render the dune surface more stable. *Oenothera viridescens* and *Chrysopsis* sp., decumbent and matted, or erect and open, according to conditions, characterize the third stage. The second line of succession begins with the salt marsh. *Spartina* sp. is the pioneer, growing in dense pure masses along the inner edge of the spit. *Salicornia ambigua* characterizes the second stage, and is followed by *Frankenia grandiflora* and the mat-forming grass *Monanthochloe littoralis.* The sifting-in of sand brings another community, dominated by *Isocoma vernonioides.* These two successional lines, having progressed to the points indicated, exhibit a strong tendency to merge, in that a final set of plants appears indifferently in both. None of these is a strictly coastal species, and several belong to the community which an incomplete study points to as the climax of the region around San Diego and southward along the Mexican coast. Among these are *Ephedra californica, Yucca mohavensis, Eriogonum fasciculatum, Atriplex canescens, Rhus integrifolia, Echinocactus* sp., *Opuntia occidentalis, Adolphia californica, Encelia californica.*

June, July, and August were devoted to the Monterey region. Here there are three localities where dunes have developed upon a considerable scale. The town of Carmel is built mainly upon an established dune complex of uncertain thickness which mantles a slope of older materials. The succession here has attained to a much more advanced stage than at Coronado, since the sand has blown inland far enough to be free from the retarding influences associated with the immediate shore, and since the history has been an actually longer one. The stages represented are as follows: (1) *Abronia latifolia* (corresponding roughly to *A. maritima* of the south); (2) semi-pioneers, including *Poa douglasii, Eriogonum latifolium, Abronia umbellata, Mesembryanthemum æquilaterale, Croton californicum, Oenothera cheiranthifolia, Convolvulus soldanella, Artemisia pycnocephala;* (3) a nearly closed community dominated by *Ericameria ericoides,* in which *Eriogonum parvifolium, Lupinus chamissonis,* and *Eriophyllum stæchadifolium* are also important; (4) chaparral, made up of *Adenostoma fasciculatum, Arctostaphylos pumila, A. vestita, Ceanothus rigidus,* and *C. dentatus;* (5) forest of *Pinus radiata* and *Quercus agrifolia.* The sand-dune succession has here plainly attained to the climax.

The second area borders the western side of Point Pinos, and is essentially like that at Carmel, but of greater extent and interest. Fresh sand trails from blowouts are here invading mature pine forest.

The third area extends along the shore of Monterey Bay from Del Monte to the Salinas River and beyond, and is of very special interest, with a complex history. It has long been the site of dune-building, so that accumulations of past centuries, mantling the older formations, now lie several kilometers back from the shore and 200 meters above it, raised to their present position by the great uplift that elsewhere is evidenced by ancient sea cliffs and terraces. A more recent subsidence of about 100 meters has resulted in the formation of a wave-cut bluff along the central portion of the mass, exposing in section the accumulations of past ages and the building of bars surmounted by new dunes across the mouths of the Salinas, Del Rey, and other streams. Repeated blow-outs along the bluff have resulted in the formation here of a distinct new line of dunes of great size, superposed upon the older. These in turn are stabilized for the most part, though occasional blow-outs show that the processes of change are still in operation.

The pioneer communities are only fragmentarily present. The ancient dune complex, being outside the pine region, is covered by chaparral and oak forest; the younger series along the shore is controlled by the *Ericameria* community. The rapidity with which this establishes itself upon new areas, together with the uniformity of its covering upon areas of unequal ages and the almost total absence of chaparral upon the younger dune series, indicates that it constitutes a subclimax of long duration, its supersession by the chaparral being impossible until a considerable amount of humus has accumulated in the soil. In the Monterey region, therefore, the long period of undisturbed development has permitted the attainment of the climax upon the oldest areas—pine forest on the peninsula, chaparral or oak in the back country.

Several permanent quadrats and transects were established in the dune region of Monterey Bay for experimental study of the successions. The plant communities of the region bounded roughly by the ocean, the Salinas, and the Carmel Rivers were accurately mapped. Ten rain-gages, arranged to sum the seasonal totals, were placed at strategic points, to aid in the solution of local climatic problems.

At both Coronado and Monterey the underground portions of the principal species—30 in all—were excavated, and many of them photographed. The results of this work can not be brought together at the present time. Material for anatomical study of 52 species was also collected, and also the seeds for experimental greenhouse study.

For habitat investigation a series of 16 stations was established, representing the peninsular and bay regions, and all successional stages. Measurements were made of soil-moisture and soil-tempera-

ture at depths of 10, 50, and 100 cm., and of evaporation covering a period of 45 days in July and August, and soil samples were collected for mechanical analysis and other determinations. Anatomical and other studies will be carried on during the winter months in the laboratory and greenhouse at the University of Minnesota.

The Origination of Xerophytism in Plants, by D. T. MacDougal and H. A. Spoehr.

The part played by aridity as an evolutionary factor in the derivation of land forms is well recognized by students of phylogeny. It is well known that only plants showing specialized habits coupled with well-defined anatomical features may continue to exist in places having pronounced desert conditions. The idea that aridity stands in a causal relation to the characters of desert vegetation bulks large in determining our thinking of these forms. It is to be seen, however, that the matter has been dealt with hitherto as if the effect of aridity did not make an impression upon the plant, its living matter, or accessory structures directly. The combined effects of rapid evaporation and undeveloped drainage in desert regions have resulted in accumulation of a greater proportion of salts in the soils than in well-watered and freely drained soils, and the strand habitats of the sea-shore succulents are also high in salts, and this has caused attention to be directed to the possible effects of these substances in inducing the succulence of plants both on strands and in the desert. The formation of the spiny plants of the desert was also attributed to the possible osmotic action of these substances.

It has long been recognized that the structure and chemical composition of a plant may be modified by its water relations during growth, but until recently available analyses did not include data upon which any explanation of the present problem might be based. This was finally found in the carbohydrate metabolism and in the imbibitional action of the mucilages and proteins in plant cells.

If we turn to the previously available analyses of plants and examine them for the purpose of determining changes in the carbohydrate-content as influenced by humidity and aridity, it will be seen that the figures show a greater amount of cellulose and a lesser amount of starch in the plants developed in the drier atmosphere.

The possible significance of the transformations in question was not realized, however, until a long series of detailed analyses of the sugar-content of the cacti was made at the Desert Laboratory. Determinations were made in all stages of development of the plant, in all the seasons, and of material subjected to various experimental conditions. Prominent among the various transformations is a change of polysaccharids into pentosans or mucilages, a conversion of carbohydrates of but little hydration capacity into others which have a large coefficient of imbibition. This change, when accompanied or followed by the

increase of the cells, results in succulence. Not all plants in which such transformations take place become succulents, but two species have been observed in which individuals growing under arid conditions become succulent and those elsewhere maintain their mesophytic character. One, *Castilleja latifolia*, was found by H. M. Richards to be characterized by a high acidity of the sap in the thin leaves and a lower acidity in the succulent individuals. It is suggested that plants which have a type of respiration resulting in a large proportion of residual acids may be capable of succulency, but this is a matter which has not yet been substantiated by any facts beyond those cited.

The depletion of the water-supply may, under circumstances as noted above, result in the conversion of polysaccharids into pentosans which take up and hold in a mucilage large proportions of water. This of course is but one of the possibilities. Under other conditions a low water-content causes the formation of the anhydrides, of which wall-substance or cellulose is an example, or, more properly speaking, such action is increased or accelerated, and the plant structure thus becomes hard and indurated, and such use of its carbohydrates is of course accompanied by a limited growth, particularly in branches and leaves where the effects of aridity would be greatest.

The separate types of transformation of carbohydrates might take place in the same plant, in different cells. Thus, some of the massive cacti have shoots from which the power of branching has been entirely lost and the stems are reduced to short, cylindrical, swollen, or globose forms. The external layers of such plants exhibit the typical xerophytic anhydrous wall-formations, while the cortical elements have been the scene of transformations of sugars resulting in succulency.

The exposure of a plant to arid conditions might be expected, therefore, to be followed by a retarded development due to the lack of water necessary for the hydration of cell-colloids in growth, by the accelerated formation of pentosans or mucilaginous material in the cells, leading to hypertrophy of the parenchymatous elements, or by the increased formation of wall material, especially in the external layers constituting the essential feature of xerophytism.

The conclusions reached in this and in previous papers are to the effect that succulence results from the conversion of polysaccharids into pentosans or mucilages, and xerophytism from a conversion of the polysaccharids into the anhydrides or wall material, both transformations being induced by a depleted or lessened water-supply in the cells.

Transpiration and Absorption by Roots of Fleshy Euphorbias, by Edith B. Shreve.

The transpirational and root-absorption behavior of 3 species of fleshy euphorbias has been studied to ascertain whether or not they have any physiological resemblance to the species of cacti which have been previously investigated. The methods used have been described

in a late publication. The euphorbias are all natives of the South African desert and do not grow naturally in the American deserts. The ratio A/T (water absorption by roots divided by water-loss by transpiration for the same period) was calculated from experimental data and found to show in general the same behavior as for cacti, *i. e.*, the ratio is greater for the day than for the night under some conditions. Accompanying this behavior there is an upward movement of branches for the day and a downward one at night. However, neither the difference between the day and night A/T ratios nor the movement of the branches was as great as in the case of the cacti. Furthermore, there were more exceptions to the general behavior than appeared in the first experiments with the cacti. The exceptions for *Euphorbia* have not been dealt with.

Seasonal Changes in the Water Relations of Desert Plants, by Edith B. Shreve.

For a number of years experiments have been conducted on a successful desert perennial, *Encelia farinosa,* and on two equally successful desert annuals, *Streptanthus arizonicus*, a winter annual, and *Amaranthus palmeri*, a summer annual, with a view to discovering any changes that may occur in their water relations with the march of the seasons. The work has now reached a stage where the following facts have appeared:

In the case of *Encelia*, the total transpiration per unit area for 24 hours was only 1.4 times as great for May as for January and September, while the total evaporation for 24 hours, as measured by the white atmometer, was twice as great for May as for January and 1.8 times as great for September as for January. In May the soil-moisture was only 0.46 of its value in January and by September it had risen to 1.1 of the January amount. If the severity of environmental conditions with reference to water be represented by the ratio of evaporation to soil moisture (E/Sm), then the conditions were nearly 4.5 times as great for May as for January and only 1.6 times as great for September as for January. The maximum leaf water-content in January was 3.5 times greater than in May. The average daily variation in January was from 5.3 to 3.6 grams of water per gram of dry weight, while in May it was less than the experimental error. Thus it appears that as the dry season advances, *Encelia* loses more water by evaporation than it absorbs by its roots until a certain minimum water-content is reached, after which the relation between outgo and intake remains around unity. In the meantime, some of the larger leaves die and the younger ones obtain a very heavy coating of hairs. But in addition to this, a viscous brown liquid is formed in the vessels which in May quickly oozes from even a slight injury, while in January no such substance is evident, even when the branches are severed.

The following theory has been formulated as a working hypothesis: The increase or decrease of some substance or substances within the tissues affects the water-attracting power of the colloidal jellies and thus brings about a greater resistance to water-loss on the one hand and a greater absorption by the roots on the other hand. This same theory was found to be valid in the case of *Opuntia versicolor*, and plans are laid for testing *Encelia* for the same phenomena.

Streptanthus evidently has no successful means of coping with the arid foresummer and so must complete its life-cycle within a month or two, or in even less time. While *Encelia* lives in the open sunshine the entire year, *Streptanthus* spends its short life in the partial shade of larger shrubs. It has the ability of quick recovery from wilting as soon as night conditions appear, but a more wilted condition each succeeding week or day is soon followed by complete failure of recovery, and it is seen that the plant has all the time been living under the most adverse conditions it can endure. Its leaf water-content has a daily variation of 5.7 to 2.7 grams of water per gram of dry weight. Although its water-content is thus as high as that of *Encelia* for the same season, and its leaf structure shows a much more mesophytic form, nevertheless its actual water-loss per unit area is only one-fourth as great as from *Encelia*. The greater exposure of *Encelia* to the sun's rays accounts for part of this difference, but probably there are other agencies responsible also.

As is the case with all desert annuals, the length of life of *Amaranthus palmeri* varies greatly with the length of the rainy season, but its ability to revive after a shower when it has remained in a continuously wilted state for three weeks makes it one of the most successful of the annuals. Wilting seems to be its only means of cutting down transpirational loss, for it loses four times as much water per unit area as *Streptanthus*, while living under conditions of aridity which are three times as great. It seems quite evident that *Amaranthus* owes its ability to withstand the high evaporation-rates of August and September primarily to the efficiency of its water absorbing and conducting systems and not to any agency which regulates transpirational loss, such as appeared in the case of *Encelia*. The results of the experiments show that *Streptanthus* could not endure the high evaporational rates of August and September and that *Amaranthus* could thrive in the spring were it not for the fact that its seeds will not germinate at the lower temperatures which are characteristic of that season.

DEPARTMENT OF EMBRYOLOGY.*

George L. Streeter, Director.

As has been our experience in previous years, the work of this department during the past year approaches our primary problem—human embryology—from several directions. It includes the microscopic structure of the individual cell and the grosser anatomy of organ systems in their different stages, as well as the body as a whole. Furthermore, our studies not only concern the morphology of normal human embryos, but it has also been found necessary to consider the abnormal and the factors involved in their causation. To some extent we have resorted to other animal forms in which experimental procedures are possible and have found the element of control introduced by experiment to be of very great assistance. In the following report these various studies will be grouped for greater convenience under three general headings: those concerning the structure of the cell, or cytology, those concerning the development and structure of individual organ systems, and finally, the clinical and pathological studies bearing on the abnormal development of the embryo. Before the description of the character and results of these studies is entered upon, mention may be made of two events in the further progress of the development of our organization.

Since 1915 our researches have been conducted in a suite of rooms in the Hunterian Laboratory of the Johns Hopkins University. These quarters, while well adapted to our purposes, are limited in space, and the extent of their capacity, as regards the housing and preparation of the rapidly growing collection, has already been reached. To meet our future needs a piece of property at the corner of Wolfe and Monument streets, suitable for a building-site, has been deeded to the Carnegie Institution of Washington by the trustees of the Johns Hopkins University, and the preliminary plans have been drawn for a four-story laboratory building 100 by 50 feet.

An important addition to our staff has been made by securing the services of Dr. Warren H. Lewis, professor of physiological anatomy at the Johns Hopkins University. His appointment as research associate was made on August 1. The work of Professor Lewis has been devoted mainly to problems in morphological and experimental embryology, in which fields his contributions are well known. Recently, in conjunction with Mrs. Lewis, he has improved the methods of cultivating embryonic tissues in artificial media, thus making it possible to follow the differentiation of growing tissues under the microscope. This procedure in their hands is yielding conspicuous results in the advance-

*Address Hunterian Laboratory, Johns Hopkins Medical School, Baltimore, Maryland.

ment of our knowledge of cell structure. In coming to us, Dr. Lewis will be freed from teaching and will thus be enabled to devote his entire time to the continuation of his research work.

CYTOLOGY.

Although the structure and function of mitochondria constitute a relatively new field of research, a great many investigations have already accumulated, and it is now found necessary to attempt to harmonize some of the results. Two papers have been published from this Department during the past year which review the present status of the problem and tend to reconcile divergent theories. Mention was made in my last report of one by Professor E. V. Cowdry, which appeared too late to be reported at length at that time. In view of the importance of this contribution, some account of it should be given here.

The consideration of mitochondria is inseparable from the fundamental problem of the structure of living protoplasm, and Dr. Cowdry presents this whole matter in a comprehensive way. In connection with his introductory account of the development of our present knowledge of mitochondria, he gives most useful summaries of the varieties of tissue-cells and of the different animal and plant forms in which they have been described, together with the names of the investigators in each instance. The wide distribution of the mitochondria, as seen from his tables, is amazing. They are found in all tissues, from man to the lowest protozoon, and from angiosperms to the fungi, though their existence is doubtful in the myxomycetes, schizomycetes, and most of the algæ. They are as characteristic of the cytoplasm as chromatin is of the nucleus. They are found in all stages of life—in the egg and in all tissues of the developing embryo and of the adult. In the part devoted to technique, morphology, and distribution, Dr. Cowdry makes use of much unpublished data of his own, as he does more or less throughout the whole contribution. In connection with the variations in the amount of the mitochondria, he points out that their presence in large numbers is associated with intense protoplasmic activity. They are especially numerous in the active stages of cell life and diminish with senility, in both plants and animals. There is a sharp increase with regenerative activity and in compensatory hypertrophy. In the second place, there is a distinct reciprocal relationship between the amount of mitochondria and the amount of fat, which suggests some connection between the mitochondria and oxidation. Their abundance in the active stages of the life of the cell, when protoplasmic respiration is rapid, points to the same conclusion. In the section dealing with the chemical constitution of mitochondria a complete account is given of the author's observations on the reaction of these structures to Janus green and other vital stains. As regards their physiology, it is clear, from Dr. Cowdry's own experience and that of others working with

him, that the mitochondria are not directly concerned with specialized activities, such as conduction or secretion, but rather with some fundamental process common to all cells; they probably participate in some of the processes involved in cell metabolism and possibly in protoplasmic respiration.

In its application to pathological conditions, the work on mitochondria puts at our disposal a new criterion of cell activity and cell injury, which heretofore have been gaged almost exclusively by nuclear changes. Mitochondria show delicate sensitivity to pathological changes and respond by variations in shape and size to injurious influences, even before the nucleus. Furthermore, the indicator in this case is cytoplasmic, and we may confidently expect it to disclose facts which would never have been revealed by a study of the nucleus alone. Favorable results have already been obtained by its application to the study of exophthalmic goiter.

Throughout Dr. Cowdry's paper there is clearly pointed out deficiencies in our present information regarding the character and rôle of mitochondria, and it abounds in suggestions and practical programs for further investigations in this fundamental field.

Another paper reviewing the status of mitochondria, or chondriosomes as designated in his terminology, is that of Professor Jules Duesberg. Investigators following the chondriosome problem will be especially interested in his discussion of the part played by these structures in fertilization and in the process of differentiation, although in these respects he does not reach positive conclusions. Benda's opinion that chondriosomes are an idioplasmic substance is definitely supported by Duesberg's description of the behavior of the male chondriosomes in *Ascaris* during fertilization. An important step was made when it was gradually shown that chondriosomes are constant in all spermatozoa of all species, although varying greatly in shape and location in the different species. The great majority of biologists originally accepted the view that the nucleus is the carrier of the idioplasm, for the obvious reason that in most cases only the nucleus of the spermatozoon was detected in the egg. When it was shown, however, that in a large number of both invertebrates and vertebrates the chondriosomes also penetrate the egg, the monopoly of the nucleus as a carrier of the idioplasm was brought up for reconsideration. Whereas the way would seem clear for the hypothesis that the chondriosomes represent the idioplasm contained in the protoplasm of the seminal cells, an obstacle is met with in the discovery that the chondriosomal part of the spermatozoon passes unchanged into only one of the two first blastomeres (bat). Dr. Duesberg meets this difficulty by suggesting that these blastomeres of the mammalian egg are not equivalent; *i.e.*, one may form the trophoblast, the other the embryo. The constancy of the chondriosomes in the spermatozoon, the lack of a satis-

factory hypothesis as to their significance, and the fact that they actually penetrate the egg, warrant a thorough investigation before they are eliminated as theoretical bearers of hereditary characteristics.

In connection with an investigation on the seminal cells of the opossum, Dr. Duesberg has extended his studies to the complex interstitial cells which are present in large numbers in the testicle of this animal. He finds that these cells contain either one or two nuclei, an idiosome with two or more centrioles, an apparatus of Golgi, some fat, crystalloids of two types, and chondriosomes. They exhibit, however, two especially noteworthy features. Due, as the author thinks, to the conditions of fixation, the chondriosomes are modified so as to form a huge framework which bears a striking resemblance to some types of Golgi's apparatus, or, perhaps, a trophospongial net. This framework is not found in all parts of the cell-body, but leaves free the periphery and a space in the immediate vicinity of the nucleus, which might safely be construed as the idiosome. The second feature is the presence of an intracellular substance which appears to be an accumulation of a granular or amorphous secretion product and which, owing to its staining properties, can be followed on the preparations into the intercellular spaces and finally into the vessels. This constitutes one of the clearest instances in which the secretion product of an endocrin gland can be actually followed from the glandular cell into the vascular system.

An important study in the phenomena associated with cell degeneration has been made by Professor W. H. Lewis. Using explants from chick embryos, he has cultivated fibroblasts *in vitro* and has observed the occurrence and behavior of certain granules and vacuoles which apparently form within them as waste products, and which he regards as a part of the process of cell degeneration. The living fibroblasts were observed over periods of one to three days, in most cases with the use of neutral red and Janus black No. 2. The neutral red dye is rapidly taken up by the vacuoles and granules, whereas the Janus black stains only the mitochondria. In this way he had a differential test which enabled him to show that the granules and vacuoles bear no relation to the mitochondria, with the exception that, as the number of granules increased, the mitochondria changed from threads and rods to granules and vesicles, and, in cases of extreme vacuolization, became lodged between the vacuoles. Degeneration granules are few in number in normal cells, but abundant in cells showing extensive vacuolization. They practically never occur in vigorous young fibroblasts, but increase progressively with the age of the culture. Their size varies from extremely minute, and probably ultra-microscopic, to half the diameter of the nucleolus. After there has been a considerable accumulation of these granules, fluid vacuoles begin to develop around them. These also vary in size, and their shape is constantly altering with

changes in position. The most common and stable form is spherical, and such vacuoles may remain unchanged for a long time. Some send out thread-like processes or channels which contain the same fluid as the vacuole, and these anastomose with other channels and form a complicated plexus. While much the same size and shape as the mitochondria, these channels change much more rapidly and, with staining reactions such as were used, there is no difficulty in distinguishing them. The granules move about actively with the cytoplasmic currents, usually in paths between the periphery and the centrosphere. At first scattered, they gradually increase in number and tend to accumulate at what appears in the early stages to be a given point. In the fixed preparations and in older cultures it is clearly seen that this point is about the centriole or centrosphere. Because of its bearing upon cell metabolism, it is an interesting and important point that the centriole and not the nucleus is most directly concerned in the accumulation and location of these degeneration granules and vacuoles. As they accumulate about the centriole, the centrosphere gradually expands and may attain a diameter equal to or even greater than the nucleus, and thus the granules and vacuoles are pushed farther and farther away. The exact cause of this enlargement is not known, but the accumulation of granules, together with the increase in the amount of cytoplasm, suggests that the activities of the centrosphere are in some way increased during the degeneration of the cell. Experiments have shown that undoubtedly some relation exists between the size of the centrosphere and the accumulation of foodstuffs in the egg, and, also, that it is larger in cells which are about to divide than in the resting cells. The question as to whether the granules and vacuoles have anything to do with its expansion now suggests itself. Such an accumulation would naturally alter the relationship between the centriole and the periphery and interfere with the metabolic balance, since the metabolic activities centered in the centriole probably depend upon a constant interchange of materials between the latter and the periphery.

Two papers have been published concerning the distribution and formation of fat droplets. It has been shown by Dr. W. A. McIntosh that normally there is fat present in the epithelial cells of the stomach and intestine of the cat which is not associated with the phenomenon of fat absorption. This normal fat appears to vary, however, according to some definite cycle of functional activity of the cells themselves, at certain periods of which their lipoid content can be demonstrated histologically, while at others this is not possible. The cats used by this investigator were deprived of food for 24 to 28 hours, by which time all evidence of fat absorption in the lacteals had disappeared. Pieces were taken from various portions of the alimentary tract and, by improved histological methods, droplets of fat were demonstrated

in the glandular cells of the stomach, duodenum, and the lower part of the small intestine, the amount varying in the different animals from a trace to large quantities. From these observations it is apparent that the normal presence of fat in these tissues must be taken into account in all future experiments on fat absorption.

As one of the rôles played by the mitochondria, it has been claimed by several observers that they form fat droplets. Mrs. Margaret R. Lewis has devised a method by which she has been able to show that fat droplets unquestionably may form in a living cell without being associated at any time with the mitochondria. To this end she stained egg-yolk with Sudan III and, diluting it with Locke-Lewis solution, placed it on 24-hour cultures of 6 to 9 day chick embryos. Since fat combined with Sudan III, when fed to animals, passes through the intestinal wall and is deposited in the body-cells in the form of red fat globules, we should expect in tissue cultures to find it deposited in the mitochondria before appearing as red fat globules in the cytoplasm; that is, if the mitochondria are fat producers. Such, however, was not the result. Within a few hours after the application of the Sudan III-yolk solution, exceedingly small, reddish-yellow fat droplets appeared in the cytoplasm of the cells entirely distinct from the mitochondria. Some of the orange-colored droplets fused, others appeared in the course of the next few hours, and in time the fat droplets originally present in the cell had taken up the stain until it was impossible to distinguish them from the new ones by their color. At no time did the mitochondria contain orange-colored droplets, nor did they become rounded, looped, or ring-shaped, or show any other supposed transitional forms.

In my report of last year I described the studies on the growth of cross-striated muscle-fibers in tissue cultures by M. R. Lewis and W. H. Lewis, and also another paper by the same authors on the contraction phenomenon of smooth-muscle cells in hanging-drop preparations of the amnion of the chick. These muscle investigations have been continued by Mrs. Lewis, who has completed a careful cytological study of the development of the heart-muscle in chick embryos of 28 hours to 4 days of incubation. By combining observations on fresh tissue with the study of fixed and stained material, she has discovered important facts regarding the development of cross-striations and their relation to myofibrils, concerning which there has heretofore been a wide divergence of opinion. The fixed material was prepared as a total mount by treating the blastoderm with a solution of corrosive sublimate 5 per cent, with the addition of a little osmic acid, and the extension of the heart was secured by the weight of the cover-slip. In such preparations Mrs. Lewis found that within the individual muscle-cell there is a gradual accumulation of some substance which, upon fixation, gives the appearance of fibrils. The type of fibrils into

which this substance develops depends upon the treatment to which it has been subjected. Thus, she was able to demonstrate complete cross-striations in all the stages studied, up to 4 days, and that fibrils are completely cross-striated from their first appearance—*i.e.*, at the stage of 10 myotomes, at which time it has heretofore been supposed that there existed only threads and granules from which the fibrils are formed. It is difficult to distinguish the heart-muscle before 10 myotomes when the heart forms a single tube composed of an outer layer of flattened cells and an inner layer of endothelial cells. In the very young embryos the muscle-tissue appeared to be in the form of a syncytium; only a few fibrils were formed at this time, but as the heart matured the number increased. In all ages they varied in width, from that of a mitochondrium to the full diameter of the cell. They were usually straight or slightly bent, but in some places curved with the outline of the cell. The wing-muscle of the house-fly and the heart-muscle of the chick, examined side by side, showed marked similarities in their cross-striations. These striations are designated by Mrs. Lewis as the *dark band*, the *light band*, and the *gray band*, and are formed respectively of Krause's membrane, hyaline substance, and sarcous substance. The most pronounced was the light band, which is lighter than the cytoplasm, for the reason that it does not become as dense upon fixation as other portions of the cell. The dark band is probably quite dense, while the gray band is practically the same as the cytoplasm. The gray band was not noticeable as a special structure, but the regular space between the two light bands indicated its presence. The characteristic appearance of the bands remained practically the same wherever found, and whether wide or narrow. In certain round cells the fibrils could not be found, but the bands were present, represented at times by granules of uniform size surrounded by a light area. For the study of living muscle the same method was used, except that a drop of Locke solution was used in the place of the fixing solution. It was thus possible to study the living heart, which continued to contract for an hour or more. In such preparations no structures resembling the fibrils in the fixed preparations were present in any of the stages studied, not even in 6-day embryos which were used for comparison. There were, in fact, no long threads of any kind. The mitochondria were abundant, as shown by the treatment with Janus green, and, although in the form of threads and rods, they did not extend far beyond the region of the nucleus. Cross-striations are present in embryos of 10 myotomes, but without careful search are difficult to observe up to 2 days of incubation. The most active cells contain them as parallel bands of light and dark material which are lost as soon as the vision penetrates below the surface of the cell. The cross-striations are, however, readily observable in the living heart when stained with Janus green, although in no instance were they as marked

in the living tissue as in fixed preparations. This is due to the fact that they were not drawn into thick bundles (fibrils), but remained spread out over the surface of the cell. It would seem probable, therefore, that cross-striations are laid down in the heart-muscle cell coincidentally with the differentiation of the latter. Whereas fibrils are not present in living tissues, upon fixation the cross-striations are drawn into fibrils and appear as sharply marked structures, varying in form according to the fixative used and the method of treatment. As the substance increases during development, naturally the appearance of cross-striations becomes clearer the older the age studied. Any attempt to formulate a theory of contraction based upon myofibrils, as has been done in the past, we now know must prove unsatisfactory, at least as regards the heart-muscle, since the structure upon which such theories have been based is not a part of the living heart-muscle cell.

Experiments have been made by Dr. J. R. Cash to determine the effect of ether-vapor on various types of cells in tissue cultures. He finds that connective-tissue cells, muscle-buds, and nerve-fibers from explants of embryonic chick tissue, when exposed to ether, develop within 1 to 3 minutes interesting vesicles which bulge out at points on the surface of the cell. These vesicles rapidly change their shape and, following sublethal amounts of ether-vapor, flow back and the cell assumes its normal appearance. After slow ether death the vesicles remain active, but when rapid death ensues the entire cell assumes a rounded form and few if any vesicles appear. Similar changes are readily produced by subjecting old cultures (3 days) to markedly hypotonic salt solution. Immediately (within 30 seconds) numerous vesicles appear and, after characteristically changing shape for a short time, flow back into the cell. Such changes are less readily produced in young, healthy cells. Similar vesicles have occasionally been noted in degenerating cultures (4 to 5 days). From these observations it would seem that such vesicles are evidence of degeneration by which changes at points in the cell-membrane occur, allowing rapid imbibition of water. In the functionally active cell this change is probably overcome by the internal metabolism of the cell.

In connection with his studies upon hydatiform degeneration, Professor A. W. Meyer made a complete examination of 61 conceptuses, both normal and pathological, for the occurrence of the so-called Hofbauer plasma-cells. These cells were originally thought by Hofbauer to be characteristic of placentæ from the fourth week on, and the vacuoles present in them were regarded as having an assimilative and digestive function. Both before and subsequent to Hofbauer there have been many speculations as to the origin and significance of these cells, the recent trend being toward the theory that they are mesenchyme cells in process of disintegration. Dr. Meyer finds that they are especially numerous in cases of hydatiform degeneration, though it

does not necessarily follow that their presence in this condition is constant. Of the 61 specimens examined, the cells were very numerous in 17, all of which showed hydatiform degeneration of the villi; 34 of the 37 specimens which contained only a few were not identified as hydatiform, and therefore their presence can not be taken as indicative of this condition, as has been maintained by some writers. On the other hand, in not a single specimen devoid of Hofbauer cells could evidence of hydatiform degeneration be found. They occurred more frequently in pathological specimens than in those classed as normal, which is what one might expect, in view of the fact that degenerative changes of the stroma are more common in the former than in the latter.

The cells were likewise more abundant in cases of advanced hydatiform degeneration. Although most of the pathological specimens showed maceration as well as histological degeneration, it was in those in which the latter condition was the more pronounced that the greater number of Hofbauer cells were observed. Therefore, a plausible hypothesis would be that whatever causes the transformation of mesenchyme cells into Hofbauer cells is also the cause of hydatiform degeneration. There appeared to be nothing characteristic in the distribution of the cells in the material examined, except that they are more numerous where the mesenchyme was degenerating. In some instances they lay in gaps and spaces in the mesenchyme of the chorion, which rendered them quite conspicuous. They also lay in areas of the chorionic membrane which had undergone degeneration. In some villi they were more numerous than the mesenchyme cells themselves, while in others they were totally absent. All stages of degeneration were noted, even to complete disappearance of the cell. Signet-ring forms were common, and nuclei in all stages of extrusion and degeneration were found. The cell boundaries were often ragged, the nuclei crenated and pycnotic, the cytoplasm granular, vacuolated, webbed, or fenestrated, until nothing remained but a shadow form without a trace of nucleus. The poorly preserved cells were larger than the better preserved ones. The smaller cells were quite circular in outline, stained evenly, and possessed a non-granular cytoplasm with a centrally placed nucleus. Binucleated and multinucleated forms (fusion products) were also noted. In these the nuclei were unequal and more oval in outline than the nucleus of the typical Hofbauer cell. Not infrequently transitional forms between the well-preserved mesenchyme and the vacuolated Hofbauer cell were observed, but as a rule the two were readily distinguishable.

In the early period of degeneration the cells have a decidedly granular cytoplasm; hence the confusion with plasma-cells and their earlier designation as *granular wandering cells*. Although Hofbauer found that in the fresh state they reacted to vital stains as did plasma-cells,

no one has shown that they do so in fixed material. This difference, however, may be due to the degree of differentiation. Since the end-form of the Hofbauer cell is a mere shadow, it may at times be impossible to determine from what type of cell it originated. This may also account for the view that these cells are degenerating blood-cells. Meyer could find no evidence to support the theory that they are of endothelial origin. Although often lying near or even in extravasations in the villi, they never were found engorged with erythrocytes or pigmented. The material examined showed their presence in villi whose blood-vessels contained no erythroblasts, and also in non-vascular villi. Degenerating erythroblasts, identical in appearance to Hofbauer cells, are occasionally seen in the vessels and even in the heart itself, but there is no proof that in the villi Hofbauer cells arise from erythroblasts.

Undoubted instances of phagocytic Hofbauer cells were never observed, although pseudo-phagocytosis was encountered; *i.e.*, binucleated cells in which one nucleus had undergone complete chromatolysis, leaving only a nuclear membrane. Nevertheless, if they arise from mesenchyme, Hofbauer cells may be potentially phagocytic, and failure to find them so may be due to a lowered vitality in consequence of degenerative changes. In some cases Hofbauer cells fuse and form large, multinucleated, and sometimes vacuolated complexes. Although closely simulating phagocytosis, these degenerate fusion products can not be regarded as living giant cells. They seem to be indicative of degeneration and death rather than of regeneration and life.

While Hofbauer cells do not wander in the sense of the leucocyte, they nevertheless do change their location decidedly. Therefore, Meyer considers that the term *wandering cell*, being a non-committal one, is less objectionable than either *lipoid interstitial cells* or *giant cells*. Since they are most frequently found in degenerate villi and not uncommonly lie in detritus, he regards these typical, vacuolated elements as degeneration products. Cells morphologically identical to them can be found elsewhere than in the localities mentioned, but we are not thereby justified in designating these as Hofbauer cells, unless we wish to extend the use of that term to degenerating and disintegrating cells of all origins.

In order to determine the distribution of clasmatocytes in the chick embryo of about 7 days' incubation, Mr. C. S. Beck made living mounts, consisting of small bits of tissue from the various organs placed in Locke solution to which had been added a little neutral red. He found that the clasmatocytes are present in the greatest number in the subcutaneous tissues, where they lie everywhere enmeshed in the loose reticulum. There are none in the epidermis. They are abundant in the submucosa of the alimentary tract, and are also numerous in the subserous tissue. There are some among the muscle-bundles of the

gut. He found very few in the liver, the mesenephros, or the metanephros, although they are abundant in the walls of the Wolffian duct. There are some present in striped muscle and in the amnion. The method was unsatisfactory for the examination of the spinal cord and the brain, although clasmatocytes seemed to be present in the region of the choroid plexus and were numerous in the pia arachnoid. In the eye a few were observed in the sclera, but none in the retina or in the choroid coat.

Using cultures and fixed preparations of the subcutaneous tissue, Mr. H. W. Vance has studied the finer structure of these same cells. He has published a preliminary account of his observations, in which he devotes particular attention to the centrosphere.

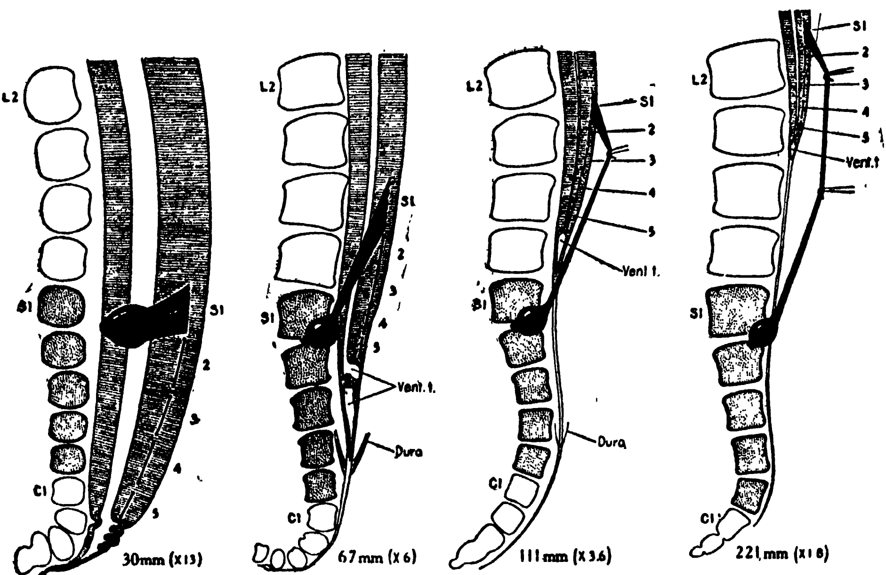
INDIVIDUAL SYSTEMS.

There have been completed four studies dealing with the central nervous system and special sense-organs, and one each concerning the lympho-vascular system and skeletal system.

In a study previously published by me on the development of the cartilaginous capsule of the ear in human embryos, I pointed out that the changes in size and form which the capsule undergoes during its development are accomplished, not only by progressive differentiation, but also in part by a retrogressive differentiation of its constituent tissues. The fact that certain areas of cartilaginous tissue revert to an earlier embryonic type and are subsequently redifferentiated into a tissue of widely different histological character, as in the case of the otic capsule, is a factor of much significance. Such a process of retrogressive change, combined with redifferentiation of the same tissue greatly increases the facilities for and the range of certain structural adjustments that occur in many regions in the development of the human embryo. Reference was made in the last report to the work done in this laboratory by Professor Kunitomo, in which he shows another instance of the same process in the case of the tail and caudal end of the spinal cord in human embryos. Working on the same structures, it occurred to me that it would be possible to determine in the formation of the filum terminale to what extent we are dealing with the dedifferentiation of the caudal end of the medullary tube, and to what extent with mechanical disproportion between the growth of the medullary tube and that of the vertebral column.

In younger stages the spinal cord and the vertebral column lie alongside of each other in a metameric manner, corresponding in position segment for segment. Owing to their disproportion in growth, there occurs a relative displacement of their segment-levels; for instance, the thirtieth segment of the cord comes to lie opposite the twentieth segment of the vertebral column. The segment levels of the vertebral column are, of course, evident; in the spinal cord they are just as

plainly marked by the attachment of the nerve-roots, for these become securely attached to the cord before the displacement begins and thus permanently mark the various segmental levels. In the case of each segment of the spinal cord there are two fixed topographical points: (1) the spinal ganglion, which is held in the intervertebral foramen and registers the original position of the segment relative to the vertebral column; and (2) the place at which the dorsal root is attached to the cord and which moves as the cord moves. By locating these points for the different stages, one can determine the exact elongation of the nerve-roots, and this in turn is the index of the relative displacement of the spinal cord as regards the vertebral column. Conversely, it will be seen that the alteration not explained by mechanical displacement must be attributed to the retrogressive changes referred to.



Topographical relations of caudal end of spinal cord in the human fetus from the eighth to the twenty-fifth week, showing formation of the filum terminale. By comparing these stages, one can determine the rate and extent of caudal displacement of the vertebral column relative to the terminal ventricle and the attachment of the sacral nerve-roots, which constitute definite and fixed points on the spinal cord. In each case the dorsal root of the first sacral nerve is drawn in, and the point of attachment of the dorsal roots of the other sacral nerves is shown by straight lines. The twenty-fifth to the twenty-ninth vertebræ were regarded as sacral vertebræ and are shown in stipple. The fetuses are listed in the Carnegie Collection as follows: No. 75, 30 mm.; No. 1656, 67 mm.; No. 1673, 111 mm.; No. 1395, 221 mm.

In this way I was able to determine that in the human embryo the greater part of the coccygeal and post-coccygeal cord—that is, the part caudal to the thirtieth segment—undergoes dedifferentiation, the more cephalic part of it persisting as the ventriculus terminalis and the more caudal part redifferentiating into a fibrous strand—the filum terminale—with the coccygeal medullary vestige at the tip. The first 29 segments of the spinal cord are not affected by this process of

dedifferentiation, but continue in a progressive development. When the embryo reaches a length of 30 mm. there begins a disproportion in the rate of growth as between the vertebral column and the spinal cord, the former elongating more rapidly than the latter, as may be seen in the accompanying figure. This results in a relative displacement of the two, the ventriculus terminalis in the 221 mm. fetus (25 weeks) lying 9 segments higher than it did originally and, by the time the adult form is attained, 2 more segments have been added to the displacement. We may say, therefore, that the filum terminale represents that portion of the spinal cord caudal to the second coccygeal segment (thirty-first segment), which has undergone dedifferentiation and has finally become converted into a fibrous strand. This strand, like the sacral nerve-roots, elongates by interstitial growth in adaptation to the ascending displacement of the spinal cord. It is of interest to note that the caudal tip of the dural sac maintains its relation to the vertebræ rather than to the spinal cord and remains attached to the filum terminale in the sacral region at a more or less fixed point.

While in Baltimore, Professor O. Van der Stricht completed a study of the development of the tunnel space, pillar cells, and the Nuel spaces in the organ of Corti, based upon histological preparations taken from young cats, bats, and common and white rats. This work is, in a way, an extension of that published by Professor Van der Stricht in volume XII of the Contributions to Embryology, and consists of a careful morphological study of these structures, concerning the development of which almost nothing was known. He finds that the tunnel space develops around the spiral nerve-bundle. Originally it is represented by an intercellular cleft, the fluid contents of which are elaborated in the vacuolated cytoplasm of the pillar cells and discharged into the adjoining space. A part of this secreting protoplasm undergoes a process of liquefaction, thus enlarging the cleft and increasing its fluid content. As the cleft enlarges the cytoplasm of the intermediate portion of the pillars decreases through a process of secretion and cytolysis until it is reduced almost to its fibrillar apparatus for support. The author describes in detail the subsequent development of the pillar cells and of their heads. The spaces of Nuel, like the tunnel, arise as intercellular clefts within which is accumulated a fluid discharge derived from the cytolysis and liquefaction of the adjacent apparatus. The fluid contents of the tunnel and of the first space of Nuel communicate with those of the second, third, and fourth spaces of Nuel. The contained fluid of all these anastomosing spaces is separated from the otic fluid of the cochlear duct by the thin membranous roofs of these interstices. Professor Van der Strict regards this apparatus as designed for the propagation of vibratory waves from the basilar membrane to the tectorial membrane contained in the cochlear canal.

An important study has been made by Dr. C. R. Essick on the structure and behavior of the arachnoidal tissue surrounding the central nervous system. He has shown that when particles of foreign matter are injected into the subarachnoid cavity of a living animal a complete transformation occurs on the part of the cells lining the space. They undergo hypertrophy, and, changing from fixed elements to free-living cells in the form of macrophages, undertake the work of removing the débris. In other words, this is an instance where cells with a specialized function revert to the more primitive rôle of unicellular organisms and engage in phagocytosis and amœboid wandering. This reaction on the part of the arachnoid cells may be brought about by the injection of inert particles, such as carbon or cinnabar, as well as by active matter, such as fragmented red blood-corpuscles or dead leucocytes. The most striking results were obtained by the injection of blood that had been partially laked with distilled water. Using cats for the experiments, a hollow needle was introduced through the occipito-atlantoid ligament and another into the lumbar subarachnoid space. In this way the cerebro-spinal fluid surrounding the spinal cord was displaced by laked blood. Within 6 hours this induced a sterile meningitis characterized by a marked increase in the leucocyte content and evidence of active phagocytosis of the fragments of the red blood-cells. At the end of 48 hours the increase of leucocytes in the cerebro-spinal fluid had subsided and microscopic examination of the meninges revealed little evidence of the injection of laked blood. The behavior of the cells lining the arachnoid space following the injection of laked red blood-cells is best studied by dissecting out the arachnoid and studying it in aqueous solutions, with or without stain. In such preparations the protoplasm of the arachnoid cells, which is normally thin and hardly demonstrable, increases in amount, so that the cell projects sharply from the trabecula. The nucleus becomes circular in outline and assumes an eccentric position. Some cells show small inclusions of fragmented erythrocytes, while others are gorged with them.

As the cells further enlarge, their attachment to the trabeculæ becomes more and more restricted, until they bud off as free amœboid macrophages, in which state they tend to become still further distended with erythrocytes and pigment. Histologically these cells, even before their detachment is completed, are identical with the large mononuclear elements which are found in the cerebro-spinal fluid in large numbers 48 hours after the onset of the reaction. Under normal conditions there occur a few of these large mononuclear cells in the cerebro-spinal fluid, and it is probable that they result in a similar way from the stimulus provided by the small quantity of tissue débris which normally finds its way into the subarachnoid space. While this reaction of the arachnoid cells is best followed on the trabeculæ, the

cells covering the membranous portion of the outer surface of the pia mater undergo the same reaction. All portions show the same degree of response, and the only requisite seems to be actual physical contact with the particulate matter. Where the collections of débris are thick, almost every cell shows signs of swelling, while adjoining regions appear relatively quiet. The detachment of the arachnoid cells apparently does not result in a true denuding of the surface, as the protoplasmic bodies of the adjacent cells, which have not detached themselves immediately, close over the gap. The activity in this replacement of cells that have budded off is evidenced by the numerous mitotic figures among the cells covering the trabeculæ. Similar experiments were carried on with suspensions of cinnabar and carbon, but phagocytosis was not so vigorous as with the erythrocytes, as the granules are slightly toxic and can not be used for food. The process is consequently slower and it may be months before all the particles are removed. Nor is the number of macrophages so great as in the experiments with laked blood, although one sees the same swelling of the protoplasm and phagocytosis of granules by the cells found on the trabeculæ.

Regarding the fate of those cells which have separated themselves from their normal environment, no additional information was obtained beyond that reported by Quincke, who showed that similar cells containing insoluble inert matter slowly wander out along the nerve-trunks and larger vessels. The soluble matter in Dr. Essick's experiments with laked blood was promptly digested and only the iron pigment remained. He found no evidence that the free cells, after leaving the trabeculæ, again assumed their former position.

Reference has been made in a previous report to the work of Professor Lewis H. Weed on the development of the cerebro-spinal spaces, and his studies showing that the arachnoid villi are essential structures in the return of the cerebro-spinal fluid into the blood-stream and that the major portion of the cranial subarachnoid space is drained by means of these structures. As a continuation of these investigations Dr. Weed has conducted a series of experiments with a view to an explanation of those poorly understood cases of internal hydrocephalus in which the obstruction to the flow of the cerebro-spinal fluid occurs within the subarachnoid space. He has found that it is possible to produce a typical internal hydrocephalus by experimentally causing a sterile meningitis. The best results were obtained by injecting into the subarachnoid space, through the occipito-atlantoid ligament, a suspension of lampblack in Ringer's solution. Young kittens in which the bony plates of the skull are not yet united, when treated in this way, rapidly (4 to 10 days) develop typical clinical symptoms such as are seen in the more chronic cases of this disease in children, the intracerebral pressure being compensated for by a conspicuous enlargement of the head. Similar results were obtained by injecting the

lampblack into the ventricles of the brain. Other insoluble granules, such as cinnabar and lycopodium, were used as an injection medium, but none of them gave rise to internal hydrocephalus. There also seems to be a difference in the reaction following the use of different qualities of lampblack.

Post-mortem examination of the kittens surviving 10 days or more shows practically identical lesions in all cases. There is extreme dilatation of the lateral and third ventricles, with distortion of the walls and marked thinning of the cerebral cortex, typical of the condition found clinically in children. The distribution of the granules is principally within the basilar and spinal subarachnoid space, with a smaller spread over the cerebral and cerebellar cortices. Apparently, the obstruction resulting from these injections is due to the aggregation of the granules into an impervious mass, the essential and ultimate matting together being accomplished by the inflammatory process which subsequently supervenes. Similar results were obtained with adult cats, though here there was no compensatory enlargement of the skull, and the results were therefore less typical.

By means of silver nitrate, forced through the omental vessels under high pressure immediately after death, Dr. H. R. Casparis has been able to clearly demonstrate the presence of lymph-vessels in the rabbit, cat, dog, and man. The silver solution passed through the walls of the arteries, invading the structures in the perivascular areas. The lymphatic endothelium was readily distinguishable from that of the veins and arteries, but in none of the experiments were the lymphatic vessels numerous. All attempts to inject them with color suspensions proved futile. The author then made a series of experiments to test absorption in anesthetized animals. The omentum was drawn out through a midline incision and kept immersed in carmine solution for varying lengths of time while absorption was taking place. All lymph-glands through which drainage might occur were removed, sectioned, and examined, but no channels of absorption were found. Smears of lymph withdrawn from the cisterna chyli and the thoracic duct were then made, and in each experiment a few granules (never very many) were found. Similar results were met with by other methods. The author was thus able to confirm the presence of lymphatics in the omentum and their function as channels of absorption from the peritoneal cavity. He has further shown that drainage from these lymphatics takes place into the cisterna chyli and on through the thoracic duct.

The canalis basilaris chordæ is generally regarded as a persisting trace of the cranial part of the chorda dorsalis which usually disappears after the third month of intrauterine life. It has been reported more frequently in children, which would indicate obliteration

during growth, but that obliteration is not the invariable rule is shown by Dr. A. H. Schultz, who reports its presence in a very old human skull. The widest and most typical canal was found in the skull of a white man 40 years of age and a narrower one in the skull of a white woman 75 years of age. It was noted also in a Filipino 30 years old, but in this case was partially obliterated. In one instance the condition was associated with a persistent sutura occipitalis transversa, forming an os Incæ verum. The posterior end of the canalis basilaris was found in 5 fetal and infant skulls, and in one of these was combined with the likewise rare persistence of a canalis cranio-pharyngeus. These two abnormal canals have several features in common: both are remnants of embryonic structures which normally disappear during the first half of intrauterine life; both are noted more frequently in children than in adults, and when present are usually partially obliterated. It is highly improbable that the canalis basilaris can be regarded as an atavism; it is much more likely to be due to an early or rapid ossification coincident with the tardy disappearance of the chorda dorsalis. More data are necessary, however, before definite conclusions as to its phylogenetic rôle can be reached.

Mention may be made here of the experiments of Dr. Schultz to determine the effect of formalin solutions upon the size and weight of fetuses during prolonged periods of preservation. He followed these changes in a series of human fetuses and also, for purposes of comparison, in a series of pig fetuses. The latter were used to detect any possible influence which the condition of the specimen at the time it is preserved might have upon later changes in formalin. Some of the pigs were preserved in an absolutely fresh state; others (from the same litter) were exposed to the air for 15 hours, and still others were kept in water for 3 days before being preserved. The condition of the specimens in the latter two series simulated respectively the state of a fetus that dies some time before it is aborted and that of a fetus that is not placed in formalin immediately after it is aborted. In neither of these series was there any apparent effect upon the later changes in size, a fact which tends to confirm the conclusion, already drawn from a study of human material, that a fetus in good condition will undergo as much change in formalin as will one in poor condition. The weight, however, increases if the specimen is preserved fresh, as contrasted to a decrease in one preserved in poor condition. After 9 months of preservation the sitting height of the human fetus was found to have decreased on an average of 2.5 per cent, while the length and breadth of the head increased 0.9 and 4.8 per cent respectively. The individual variations were quite marked. The greatest and most rapid changes occurred in the first few weeks of preservation. The absolute size appears to have no influence upon the relative amount of change in the measurements studied.

CLINICAL AND PATHOLOGICAL STUDIES.

For the purpose of securing more definite information regarding some of the factors in the occurrence of spontaneous abortion, a study has been made during the past year by Dr. J. W. Harris of a series of cases connected with the 1918 epidemic of influenza. Owing to the severity and wide occurrence of the epidemic, and to the fact that it was especially prevalent among young adults of the child-bearing age, it offered the best opportunity we have perhaps ever had to study the extent to which the progress of pregnancy is interfered with by an acute, severe, infectious disease. A questionnaire was prepared which included data as to the race and age of the individual, the month of pregnancy, whether the disease was complicated by pneumonia, the outcome for the mother (recovery or death), and whether or not pregnancy was interrupted. Copies of this blank were sent to all of the physicians of the State of Maryland and also to members of the American Gynecological Society, the American Association of Gynecologists and Obstetricians, and the local obstetric societies in four of the larger cities. This met with a most satisfactory response on the part of the physicians, and 1,350 cases of influenza occurring in pregnant women were reported in full detail. Of these, 791 were from the State of Maryland, and hence the great majority of the cases studied ran their course under the same general conditions. In race the patients were predominantly white, the proportion being 1,266 white, 82 negro, and 2 Japanese. In making this statistical study the assumption was made that these particular cases were serious enough to require medical attention, and, for the most part, did not include the very mild infections. It is to be assumed further that the material gathered is not representative of the number of cases falling within the first two months of pregnancy, when gestation might easily escape the knowledge of the physician.

With these two reservations the results of the study show, in the first place, that in the cases of influenza which were not complicated by pneumonia the pregnancy was interrupted in 26 per cent, the frequency being slightly less marked during the middle third of pregnancy. This ratio is not greatly in excess of the frequency one would expect under ordinary conditions, so it is probable that many of these abortions would have occurred in the absence of the disease; or, at least, the disease may have served only as a terminal factor in bringing about the abortion of an ovum already pathologic. On the other hand, when the influenza is complicated by pneumonia, the frequency of abortion is doubled, being 52 per cent in 585 cases, and is still greater (62 per cent) in the cases ending fatally.

In view of the prevailing opinion that the presence of influenzal pneumonia nearly always causes an interruption of pregnancy, it is of interest to note the surprising fact that in 38 per cent of the fatal

cases the patients died without aborting. This would indicate that when the ovum and the placentation are normal it requires an extremely severe disturbance in the condition of the mother to bring about the termination of pregnancy.

As regards the course and prognosis of influenza in pregnant women, it was found that about one-half of all the patients developed pneumonia, and of these about 50 per cent died, giving a gross mortality of 27 per cent. In those developing pneumonia the mortality was somewhat higher in the last 3 months of pregnancy, reaching its highest point (61 per cent) in the last month. Where the disease is complicated by abortion or premature labor the prognosis appears to be more grave. In 383 cases of pneumonia in which pregnancy was not interrupted, the mortality was 41 per cent, whereas in 395 cases in which it was interrupted there was a mortality of 63 per cent.

Professor A. W. Meyer has made a special study of double-ovum twins in which the two embryos present marked differences in size and development. He found four specimens of this character in the Carnegie Collection, and his examination shows that in each case one twin died and was retained until the birth of the other, which resulted in a considerable difference in their apparent ages. The discrepancies in size ran as follows: No. 587 (*a*) empty chorion, (*b*) cylindrical embryo 7 mm.; No. 788 (*a*) stunted embryo 17 mm., (*b*) nodular embryo 3 mm.; No. 1840 (*a*) normal embryo 31 mm., (*b*) normal embryo 15 mm.; No. 2036 (*a*) normal embryo 87 mm., (*b*) macerated embryo 23 mm. Similar discrepancies in the size of the chorions may or may not occur.

It is clear that such cases might easily be classed with the alleged instances of superfetation found in the literature, although undoubtedly it would be a misinterpretation of the facts. Dr. Meyer points out that it is such cases of twin pregnancy that are responsible for the prevalent belief in the occurrence of superfetation in women, for the existence of which he finds no real evidence.

In addition to the light which it throws upon superfetation, the preceding paper is of importance in connection with the question of retention of the chorion after the death of the embryo, and Dr. Meyer has extended his studies to the consideration of this subject. Although there is abundant evidence of the phenomenon of retrogression and partial as well as total intrauterine absorption of the conceptus in several of the mammals, the literature has thus far shown no conclusive evidence regarding its occurrence in man. Marked maceration, putrefaction, and dissolution of the human fetus are well known, but cases of intrauterine autolysis and absorption of the entire conceptus have never heretofore been reported. Retention of the conceptus after the death of the embryo is extremely common and is the usual thing in unprovoked abortions. Of 2,000 cases in the Carnegie Collection, 12.8 per cent showed advanced intrauterine disintegration, only villi

being left. Dr. Meyer describes 6 specimens in which there is clear evidence of almost complete intrauterine absorption. In one of these there remained only a few vestiges of syncytium and trophoblast which had been aborted in an entire and intact decidua. The condition of the decidua shows that a considerable regeneration of the endometrium had occurred. Also, in tubal and ovarian pregnancies there occurs a similar lysis and absorption of many of the specimens.

The possibility of the disintegration and spontaneous disappearance of the conceptus in ovarian pregnancy modifies the generally accepted criteria as to what constitutes an authentic case of this supposedly rare condition. If such absorption does occur, as is maintained in the paper of Meyer and Wynne, then the entire absence of remnants of the conceptus does not positively exclude a case from the category of true ovarian pregnancy. These authors regard most of the cases of so-called hematocele, hematoma, blood-cyst, and rupture of the ovaries as possible cases of ovarian pregnancy in disguise. They include in their study the report of a case in which the clinical and histological data are particularly complete and which, from an anatomical standpoint, is wholly unequivocal.

Continuing her investigations on spina bifida, Dr. Theodora Wheeler has extended them to include the various rudimentary forms of the anomaly, as characterized by incomplete closure of the dorsal vertebral laminæ. From an examination of 1,000 X-ray plates of the lumbar region and several thousand cervical vertebræ in the National Museum at Washington, together with cases reported in the literature, Dr. Wheeler finds that the order of frequency of incomplete closure in the various regions is as follows: (1) first sacral; (2) entire sacrum; (3) last lumbar; (4) atlas.

In this connection reference may be made also to a paper published by Mr. S. T. Wallis Cull on a fetal spina bifida monster. This specimen, although having a menstrual age of only 79 days, presents abnormalities of brain, spinal cord, viscera, and skeleton generally supposed to be characteristic of only much older monsters. The author thus adds further evidence to the view that the cause of spina bifida dates back to the early part of pregnancy.

DEPARTMENT OF EXPERIMENTAL EVOLUTION.*

C. B. Davenport, Director.

The work of the Station for Experimental Evolution has during 1919 emerged from its war status of comparative quiescence in its strict work to one of renewed activity. Many of the staff who have returned from army service are doing so with keener zest for the work that they regretfully laid aside and a resolution to bring to fruition many matters that had been long developing. On the other hand, the expense and waste of war still have their effect, and will for years to come, upon the cost of carrying on scientific work.

Among the principal advances of the year have been:

(1) The completion of the evidence that the offspring of alcoholized rats, to the second generation, are less capable of learning than the controls. This suggests an alteration of the germ-plasm by alcohol.

(2) The evidence of a certain amount of testicular degeneration in consequence of the use of alcohol.

(3) Further evidence, by the method of correlation, of the inefficiency of "selection" after the gametic factorial composition has been simplified in the earliest generations.

(4) Evidence that "staleness" of sperm does not influence the sex-ratio in pigeons.

(5) Statistical demonstration of the great increase in the proportion of males born from "hybrid" as opposed to "pure" matings in man.

(6) Statistical evidence that more still-births occur in "pure" than in "hybrid" matings; and that in "pure" matings there are relatively more males in first-born children than in later births.

(7) The discovery that species of *Portulaca*, like some other plant species, break up into numerous biotypes, including a dwarf form, and that they show abundant bud mutations.

(8) The dwarf *Portulaca* is a Mendelian recessive; so too is the weeping character of a mulberry tree as opposed to the erect form.

(9) The demonstration of four factors for color in dogs, one occurring in a triple allelomorph series.

(10) A demonstration of the chemical lack of differentiation in the brains of ataxic pigeons.

(11) Demonstration of the law of osmotic concentration of phanerogamic epiphytes as compared with their hosts.

(12) The determination of correlations between age, weight, and pulse-rate and body surfaces, on the one hand, with each other, and, on the other hand, with heat production and gaseous exchange, for men, women, and children.

(13) Statistical demonstration of the non-validity or insufficiency of the body-surface law of human basal metabolism.

---

*Situated at Cold Spring Harbor, Long Island, New York

REPORTS ON INVESTIGATIONS IN PROGRESS.

THE GERM-PLASM AND ITS MODIFICATION.

COMPARATIVE STUDY OF THE CHROMOSOME GROUPS IN DIPTERA.

Dr. Metz has resumed his studies on spermatogenesis in *Drosophila* and other Diptera. Studies on *D. virilis* and on two species of Asilidæ were almost completed by September.

COMPARATIVE GENETICAL STUDIES OF DROSOPHILA.

During the past year, Dr. Weinstein, while caring for the mutant stocks, analyzed the relationship between certain of the mutant characters in *Drosophila virilis* that had not previously been fully analyzed. Since Dr. Metz has taken up the work, considerable progress has been made in obtaining new mutant characters in *Drosophila virilis*, *D. obscura*, and *D. willistoni* and in analyzing their mode of inheritance in accordance with the plan outlined previously for ascertaining the chromosomal and genetical relationships between different species of *Drosophila*. He states that 23 new mutant characters were found in the five months, March to July inclusive.

MODIFIABILITY OF THE GERM-PLASM BY ALCOHOL.

The effect of alcohol on the capacity for forming habits (as a test of intelligence) and the recurrence of the effects in later generations of the alcoholized ancestors have been the subjects of Dr. E. C. MacDowell's research for several years. This year there is no new experimental work to report. Dr. MacDowell reports as follows:

"During four years data were continuously being collected; very little time for their summarization, or even primary tabulation, was available. It has seemed important to complete the tabulation and the analysis of these extensive masses of data and publish the results before again becoming too deeply involved in the carrying on of new experiments. Besides their significance for the primary question as to the modifiability of the germ-plasm, these data will provide evidence upon such problems as growth, the relative significance of different criteria for judging animal behavior, and the immediate effects of alcohol upon mental and physical traits. In view of the large amount of time and money that has been spent upon the collection of these data, the greatest possible use should be made of them. The hazards of deciding mental problems in terms of numbers are great enough in themselves, without leaving any suspicion that the conclusions may depend upon the special statistical treatment employed. To guard against this danger, it will be necessary to treat the data in various ways, using different combinations and methods of averaging. The intensive study of the individual record-sheets showing the track followed in each trail of every rat will serve as an important check upon the statistical results. The conclusions reached from the study of the relative value of the various criteria employed will have a close bearing upon the general conclusion. Three different experimental methods have been employed, and the degree of success in each one is measurable in various ways. When Miss Vicari left this laboratory to enter the University of Minnesota under Professor J. B. Johnston, she took with

her a set of these rats in order to preserve the lines and to obtain later generations. Various adverse conditions defeated this purpose. She reports upon this attempt as follows:

" 'An attempt was made during the year of 1918–19 to continue the alcoholization of Dr. MacDowell's strain of rats into the third generation for further study to be taken up after the war. The first and second alcoholized generations and their offspring having been studied, the aim was to breed for the third alcoholized generation, from which it was hoped to obtain material for further study of the effect of alcohol on the germ-plasm. With this point in view, a few of his rats were transferred August 18, 1918, to the Institute of Anatomy of the University of Minnesota, where I could see to the experimental part of the work during my stay at that institution. This was made possible through the kindness of Dr. C. M. Jackson, who granted all the housing necessary for the animals and the help of the service-boy.

" 'Three pairs of alcoholized rats of alcoholized parents with their respective controls made the material for obtaining the third generation of this strain. In addition to these a group of 5 test rats (non-alcoholic, but of alcoholized parents and alcoholized grandparents) was transferred for the study of fertility. This group had been trained in the circular maze and in the multiple choice or trial-and-error problem. Still another group was added. This consisted of a litter of 5 rats (F_1) which were the result of a cross of white with pink-tipped hair. This character I had noticed in Dr. MacDowell's stock during the year 1918. In seeing the material while on a visit to this Station, Dr. Castle suggested that this trait could be a possible allelomorph of albinism, or that such coloration of albino hair might be a skin secretion and not a true hair-pigment. The aim was to carry the cross into F_2 to see if the trait of pink-tipped hairs is inherited and in what manner.

" 'At Minnesota the rats did not fare well. After a strenuous journey they had to readjust themselves to new environmental conditions, such as temperature, cage conveniences, and a change of diet. They had been accustomed to receive a daily ration of wheat bread soaked in fresh milk and all the dog bread they wanted. This dog bread was a special make, which, according to the chemist, Mr. Halloway, is a well-balanced food for animals or men, and hence had the necessary vitamines. The change was from this diet to bran bread soaked in fresh milk and dry corn. After a month of this diet the rats had lost from 10 to 22 per cent in gross body-weight. The mortality was high, and in order to save the stock their former diet was restored in November. From the three pairs of alcoholized rats offspring were obtained and four matings made. These were alcoholized from the time of weaning (28 days), but no offspring were had from them, though they lived to maturity. During the winter an epidemic of a digestive disorder took a few of the rats away. Of the second and third group of rats, breeding was continued and the results of fertility and color inheritance recorded.

" 'The hope of saving the alcoholized strain was not realized, principally on account of the lack of reproduction, the mortality, and the environmental conditions.'

"This summer all the time of Miss Vicari has been devoted to the rat data. To obtain a preliminary survey of the results bearing most critically upon the question of the inheritance of the changes caused by the administration of alcohol, the work has been focused upon the rats whose grandparents only had been given the alcohol treatment, and upon the controls, rats whose grandparents were normal, the brothers and sisters of the alcoholized grandparents of the rats under consideration. A year ago (Year Book, 1918, pp. 109–114) Miss Vicari gave the preliminary summaries for a group of 5 such

rats with their normal controls. In this case there appeared clearly a difference between the two sets of rats. The test animals (from alcoholized grandparents) were inferior to the controls by various criteria. We are able to present, at this time, similar preliminary summaries of 36 more rats from like experiments—18 *test* rats from alcoholized grandparents and normal parents, 18 *controls* from normal grandparents and normal parents.

"Two tables, giving the results from the training on the maze and the multiple-choice apparatus respectively are given. It must be noted that these figures are subject to correction upon subsequent checking. The numbers in the body of the tables are the averages of all the individuals in one family. In each case the number of rats included in the average is shown. By an experiment is meant a litter of test rats and the corresponding control litter. The averages of 'all experiments' are the primary averages of the individuals' averages in all experiments.

"Table 1, the results of the training on the multiple-choice apparatus, gives the comparative averages of the test and control litters under five different experimental situations as indicated in the first column. The averages for

TABLE 1.—*Comparison of rats from alcoholized grandparents with normal controls. Summary of results of training on multiple-choice apparatus.*

Nature of training.	Exp. No.	Based on correct first choices.					Based on wrong choices.				
		Tests.		Controls.		Controls better.	Tests.		Controls.		Controls better.
		Av.	No.	Av.	No.		Av.	No.	Av.	No.	
Right-hand training proper.	19	3.62	5	2.42	5	−1.20	12.68	5	16.84	5	−4.16
	20	3.88	5	6.25	5	+2.37	12.44	5	7.42	5	+5.02
	21	4.70	2	6.10	2	+1.40	11.05	2	6.60	2	+4.45
	22	4.40	3	4.07	3	− .33	10.60	3	10.16	3	+ .44
	23	3.47	8	4.03	8	+ .56	13.31	8	11.24	8	+2.07
All exps..	....	3.82	23	4.35	23	+ .53±0.26	12.39	23	11.08	23	+1.31±0.69
Test set-ups...	19	4.90	5	2.70	5	−2.20	10.50	5	15.50	5	−5.00
	20	4.96	5	6.18	5	+1.22	7.00	5	5.90	5	+1.10
	22	4.33	3	4.33	3	.00	11.86	3	9.33	3	+2.53
	23	6.00	8	6.07	8	+ .07	6.87	8	7.40	8	− .53
All exps..	....	5.24	21	5.04	21	− .20± .35	8.47	21	9.40	21	− .93± .88
Left-hand training proper.	19	3.00	5	5.72	5	+2.72	14.59	5	9.20	5	+5.39
	20	3.92	5	3.66	5	− .26	14.60	5	13.40	5	+1.20
	22	4.90	3	4.96	3	+ .06	11.30	3	13.20	3	−1.90
	23	3.76	8	4.90	8	+1.14	13.40	8	9.92	8	+3.48
All exps..	....	3.78	21	4.80	21	+1.02± .30	13.66	21	11.04	21	+2.62± .73
Test set-ups...	19	2.80	5	5.90	5	+3.10	13.30	5	7.90	5	+5.40
	20	3.10	5	3.60	5	+ .50	14.30	5	14.00	5	+ .30
	22	3.50	3	4.00	3	+ .50	11.60	3	12.30	3	− .70
	23	4.81	8	5.12	8	+ .31	10.50	8	7.93	8	+2.57
All exps..	....	3.74	21	4.78	21	+1.04± .32	12.23	21	10.00	21	+2.23± .84
Memory......	19	3.50	5	4.38	5	+ .88	12.70	5	10.65	5	+2.05
	20	3.10	5	4.65	5	+1.55	16.05	5	10.15	5	+5.90
	22	2.83	3	4.33	3	+1.50	16.00	3	11.33	3	+4.67
	23	3.57	8	3.45	8	− .12	15.76	8	12.21	8	+3.55
All exps..	....	3.33	21	4.09	21	+ .76± .29	15.48	21	11.22	21	+4.26± .59

'training proper' (learning to enter the first door to the right or left of a variable series of opened doors) are based upon 100 trials per rat; 'test set-ups' (a different variable series of opened doors requiring the same solution) are based upon 20 trials per rat; the averages for 'memory' are based upon 40 trials per rat. Each series of trials may be judged in two ways—upon the number of times a rat chooses the correct door first and the number of wrong choices he makes on the average before choosing the correct door. Accordingly, the table is divided into two parts, the two sides being different methods of describing the same reactions of the same rats. In the columns headed 'Controls better' the difference between the test and the control averages is shown with a plus sign when the controls have more correct first choices and fewer wrong choices.

"In table 2, the results of the training on the maze, the right and left halves represent the two different experimental situations, and the first column gives three different methods of judging the same reactions. The meanings of these headings is fairly obvious.

TABLE 2.—*Comparison of test rats from alcoholized grandparents with normal controls. Summary of results of training on the maze.*

Criteria of comparison.	Exp. No.	Training proper.					Memory, based on last 12 trials.				
		Tests.		Controls.		Controls better.	Tests.		Controls.		Controls better.
		Av.	No.	Av.	No.		Av.	No.	Av.	No.	
Time (av. per day in secs.).	19	31.25	5	23.01	5	8.24	21.05	5	22.35	5	− 1.30
	20	18.89	5	10.14	5	8.75	14.15	5	15.69	4	− 1.54
	21	9.25	1	14.64	2	−5.39	.....	...	.....	...	....
	22	42.14	3	17.09	3	25.05	23.47	3	20.87	3	2.60
	23	20.64	8	25.14	8	−4.50	26.16	8	14.88	8	11.88
	24	34.03	2	33.38	2	.65	28.97	2	59.23	2	−30.26
All exps..	....	25.81	24	20.75	25	+5 06±2.05	22.33	23	17.03	22	+ 5.30±2.50
Number of perfect trials, av. per rat.	19	.40	5	.60	5	.20	1.22	5	2.00	5	.78
	20	.40	5	5.20	5	4.80	2.20	5	5.40	5	3.20
	22	.33	3	2.00	3	1.67	2.66	3	4.00	3	1.34
	23	2.50	8	1.62	8	− .88	3.25	8	4.75	8	1.50
	24	1.50	2	.50	2	−1.00	4.00	2	2.50	2	− 1.50
All exps..	....	1.21	23	2.13	23	+ .92± .43	2.56	23	4.00	23	+1.44± .367
Errors (av. No. per rat per day).	19	4.67	5	3.49	5	1.18	3.01	5	3.10	5	− .09
	20	3.26	5	.76	5	2.50	1.78	5	1.37	5	.41
	22	3.93	3	1.91	3	2.02	2.57	3	1.30	3	1.27
	23	2.06	8	2.68	8	− .62	2.10	8	1.46	8	.64
	24	2.41	2	3.50	2	−1.09	1.70	2	2.41	2	− .71
All exps..	....	3.16	23	2.32	23	+ .84± .26	2.25	23	1.86	23	+ .39± .22

"An 'error' is a wrong turn in the maze; its definitions have been carefully worked out and different types of error are recognized. These will form a special study later on. A perfect trial is run when no error is made. The same method of averaging has been used in the averages for all experiments as used for the multiple-choice results.

"In observing these figures it must be clearly realized that there are many factors influencing the results that are entirely blotted out by this sort of lumping together. No final conclusion should be drawn from such averages until all the influences back of them have been thoroughly analyzed. At the

same time, it is possible to obtain a fair opinion as to the general nature of the final conclusion from these figures. The basis of the interpretation of these tables must be the comparison of the test and control litters within one experiment. In averaging different experiments together, the differing numbers of individuals from different lines introduces a source of error that may seriously modify the figures obtained. Such averages are only given to help obtain a rough general impression of the nature of the results, but only by following one set of rats through the 10 criteria of comparison for the results of the multiple-choice problem and the 6 criteria for the maze results can a correct impression of the meaning of these numbers be obtained. It is obvious that all these criteria do not bear equal weight; 'training proper,' for instance, bears much more weight than either 'test set-ups' of 'memory,' on account of the larger numbers of trials involved. In the maze all criteria are based on the same numbers of trials, but it is a question whether speed or the number of perfect trials should have more or less weight, etc.

TABLE 3.—*Summary of the comparisons given in tables 1 and 2 of the four main experiments.*
[The capital letter signifies the superior litter. T = tests superior; C = controls superior.]

Litter.	Experiment No. 19.		Experiment No. 20.		Experiment No. 22.		Experiment No. 23.		Experiment No. 24.	
	Tests.	Controls.	Tests.	Controls.	Tests	Controls.	Tests.	Controls.	Tests.	Controls.
Maze:										
Training proper:										
1. Time	......	C	......	C	......	C	T	......	......	C
2. Perfect trials	......	C	......	C	......	C	T	......	T	......
3. Errors	......	C	......	C	......	C	T	......	T	......
Memory:										
1. Time	T	......	T	......	......	C	......	C	T	......
2. Perfect trials	......	C	......	C	......	C	......	C	T	......
3. Errors	T	......	......	C	......	C	......	C	T	......
Multiple choice:										
Right-hand problem:										
2. Correct choices	T	......	......	C	T	......	......	C	Not trained.	
2. Wrong choices	T	......	......	C	......	C	......	C	......	......
Right-hand test set-ups:										
1. Correct choices	T	......	......	C	Same.		......	C	......	......
2. Wrong choices	T	......	......	C	......	C	T	......	......	......
Left-hand problem:										
1. Correct choices	......	C	T	......	......	C	......	C	......	......
2. Wrong choices	......	C	......	C	T	......	......	C	......	......
Left-hand set-ups:										
1. Correct choices	......	C	......	C	......	C	......	C	......	......
2. Wrong choices	......	C	......	C	T	......	......	C	......	......
Memory:										
1. Correct choices	......	C	......	C	......	C	T	......	......	......
2. Wrong choices	......	C	......	C	......	C	......	C	......	......

"Table 3 has been made to assist in deciphering the confusing mass of comparisons in the other tables; it shows which litter in each of the 5 experiments was found to be superior for each of the 16 criteria. This takes no account of the numbers of individuals included, nor of the amount of difference, but merely indicates the directions of the differences found. In the case of experiment 20 there are only two exceptions to the superiority of the controls; it would seem safe to conclude that there was a difference between the two litters in this experiment. But in experiment 19 the case is by no means so clear. Does the superiority of the *tests* in the 'time' and 'errors' criteria of

the memory-maze and in the first half of the multiple-choice training indicate more than chance? If so, does the possession of alcoholic ancestors in general tend to favor the success of rats judged on these criteria? This last question is answered by the comparisons in experiments 23 and 24, in which the *tests* are better in the *maze*. In all but two of the 16 criteria, some cases have been found where the *tests* are better; the two in which they have not been found are in the left-hand problem with the test set-ups in the multiple-choice apparatus when judged by correct choices and in the multiple-choice, memory, when judged by wrong choices.

"When the averages for individual rats in all experiments are averaged for each criterion, the sign of the difference is plus in every case, that is, favoring the controls. Many of these differences are not large, and when the test of the probable error is applied, it appears that only in 6 cases may they be claimed to be statistically significant, that is, probably due to other causes than chance. In only 1 case are the different criteria for the same actual performances significant; this is in the left-hand training proper on the multiple-choice apparatus. There are 2 other cases of differences that are significant on the multiple-choice apparatus, namely, left-hand test set-ups, when judged by the number of correct first choices (when judged by the number of wrong choices the difference is so small that it falls within the range of chance variations), and the memory trials when judged by the number of wrong choices. The two significant differences found in the maze criteria occur in the training proper when judged by the number of errors per day (these same reactions of the rats when judged by the time and the number of perfect trials do not show significant differences) and in the memory trials, when judged by the number of perfect trials.

"At first glance the result seems clear and the conclusion to be drawn fairly obvious—that the alcoholized 'test' strains are mentally inferior; but, as has been indicated, the correct interpretation can not be finally made directly from these averages. Much detailed study will be required before any generalization can be drawn."

CYTOLOGICAL STUDIES OF ALCOHOLIZED RATS.

The study of the cytological condition of the testes of the male alcoholized and the control rats produced in the course of these experiments was made by Dr. Ezra Allen, of the Wistar Institute of Anatomy and Biology, and results of the study were published in the Anatomical Record for April 1919. Very briefly, his findings are:

"There is testicular degeneration in both alcoholized and normal rats, but this is much greater in the alcoholics."

In addition to the alcoholized rats, Allen used, for the sake of comparison, rats that had been raised on a diet deficient in water-soluble vitamines, but found the same sort of degeneration as in the alcoholized rats. Other investigators have found the same type of degeneration as a result of subjection of the gland to the X-ray. It appears then that similar states of degeneration may arise in the testes of rats through subjection to the X-ray, through deficiency in vitamines and through alcoholization. Allen concludes that the immediate cause affecting growth and cell-division of the germ-cells is identical in all three cases.

NEUROLOGICAL STUDIES OF ALCOHOLIZED RATS.

In order to see if there was any structural difference in the brains of alcoholized rats or their descendants that were slow in learning and the brains of the controlled series, Miss Vicari has undertaken histological studies of the brains of the two sets. The comparison of the histological studies of alcoholized and normal rats bears the same relation to their capacity for learning as a comparison of the structure of the testes in the two groups bears to the subject of growth and fertility. Miss Vicari makes the following statement concerning her work:

"Brains from about 20 of Dr. MacDowell's rats, including tests and controls, were collected before leaving this institution. They were fixed for the study of degeneration. In Dr. J. B. Johnston's laboratory at the University of Minnesota this material was dehydrated, cleared, and blocked. I wish to express my appreciation of the suggestions of Dr. Johnson and of his advice as to the treatment and possible method for the histological study of this material; also of his courtesy in offering the use of his laboratory for the preparation of this material."

The preliminary results of the studies of MacDowell upon alcoholized rats thus confirm, in a general way, the conclusions of Stockard, namely, that alcohol affects not only the soma but also the germ-cells carried by the individual alcoholized, and that these germ-cells are so altered that the individuals developing from them show striking limitations in their capacity for full mental development, and this incapacity shows itself even in two generations removed from the alcoholized individuals. It looks very much as though alcohol was able sometimes to affect germinal material, probably specifically the chromosomes, so that it can no longer determine normal nervous development. The conclusion is so important, as almost the only successful means of modifying the germinal material at will, that the experiment deserves repetition. Further investigation of other methods of modification of the germ-plasm is also desirable.

ALTERATION OF THE QUALITY OF A POPULATION BY SOMATIC SELECTION.

Experiments with Drosophila.—One of the noteworthy discussions among geneticists in recent years has been that of the possibility of the contamination of genes in consequence of hybridization. This had been tied up with the question of the possibility of modifying a race in a desired direction purely by a process of selecting somatically. There has, indeed, been no dispute that a mixed race, or one in which a given trait depended upon a number of separate genes or germinal determiners, might be secured in a simpler condition through hybridization and selection for breeding of individuals whose somatic condition indicated a simple condition of their gametic makeup. The dispute was rather whether genes were, through a process of contamination or other, definitely variable so as to offer an unending stream of condi-

tions by which the experimenter might carry his strains definitely in any desired direction. It was the opinion of the great majority of experimentalists that the capacity of improvement by selection was definitely limited, owing to the fact that the number of kinds of genes available in the formation of a given organism is limited. On the other hand, Castle, to refer only to the most striking investigator in this field, accepts the view of unlimited capacity for modification through individual selection. This controversy is now to a large extent settled, chiefly through certain experiments of Castle himself, which have led him to reject his doctrine of contamination of genes, and apparently also of indefinite variability in them.

Castle's decision is, however, a matter of the last few months only, and meanwhile Dr. MacDowell has carried through an elaborate series of breedings upon *Drosophila* to determine whether the number of certain bristles on the back might be increased or diminished by selection of parents with an increased or diminished number of such bristles. As set forth in the Year Book for 1917, Dr. MacDowell reached the conclusion by the ordinary methods of genetical analysis that an indefinitely large change in the number of these bristles could not,as a matter of fact, be produced through the ordinary processes of selection.

Dr. MacDowell has now made a further statistical analysis of the data by means of the methods of correlation. Many calculations were required, and revised tables and charts and the text have been completed under the title, "Bristle Inheritance in Drosophila III. Correlation." The same conclusions are reached as by the ordinary method of genetic analysis. In brief, the correlations indicate that there was a tendency in the first five generations for the bristle grades of the offspring from high-grade parents to be higher than the bristle grades of the offspring from low-grade parents; that in no other period of the 54 generations did such a clear difference exist between the offspring of high and low grade parents; and that, when the environment was rendered as uniform as possible, no sign of any such relationship was found. In the generations where a difference was found between the offspring of high and low grade parents, it is obvious that the breeding of high-grade parents exclusively would raise the means of the race. The means actually obtained in the different generations of selection experiments show a close connection with the amount of correlation found. The means rise in the generations where the closest correlation is found. Selection has been dealing with hereditary units that were present in the original flies; it has not caused the origin of new units; its action has been to reduce the amount of genetic differences between individuals, whereas the primary requirement for evolution is that it should act so as to increase the amount of such differences. Natural selection acts as a stabilizer of evolving races; it has no part in the evolving itself.

Experiments with Daphnia.—Dr. A. M. Banta has completed the work of compiling a large number of statistics gained from his experiments on the possibility of modifying the reactions of Entomostraca to light by ordinary selection. One of the most extensive of his breeding-lines is known as line 757. In it, following selection, strains that reacted very dissimilarly appeared. In this line there is little, if any, relation between vigor and reactiveness to light, so that the effect of selection secured in this line was not due to changes in the relative vigor of the plus or minus strains, that is, of the strains selected for quicker and those selected for slower phototactic response. Dr. Banta says that the divergence of the two strains can not readily be explained as due to mutation, for there is no point in the curve where mutation may be said to have occurred. The other lines, however, generally show no effective selection, and, therefore, some special explanation has to be sought for to account for the divergence of the reaction-time in the plus and minus strains of line 757. It is now proposed to start a test series to see if the effect of selection within line 757 has persisted. So far as results are secured, they seem to show that the effect does indeed persist, although $2\frac{1}{4}$ years have elapsed since selection within these strains ceased.

The principal result of our attempts to accentuate differences by breeding plus and minus strains in flies and *Daphnia* is to indicate that improvement is effected this way only until such time as a hybrid or complex condition of the genes of the trait in question is reduced to the simplest degree.

THE SIGNIFICANCE AND CONTROL OF SEX.

SEX IN PIGEONS.

During the absence of Dr. Riddle from Cold Spring Harbor, his assistant, Dr. Ellinor H. Behre, has completed a test of the hypothesis that the relative staleness of sperm might be responsible for abnormal sex-ratios. This experiment was suggested by the findings of other investigators, especially among amphibia. It has been found that the length of time during which pigeon sperm-cells retain their capacity to fertilize may vary somewhat, but probably in any case does not exceed 8 days. It is clear, however, from the evidence, that stale sperm does not affect the sex-ratio. This is of some importance, since it shows that the very abnormal sex-ratios obtained in Dr. Riddle's work with the pigeons is neither complicated nor explained by this fact.

SEX INTERGRADES IN DAPHNIA.

As pointed out in earlier reports, Dr. Banta has had the good fortune to find interesting and significant variations from the normal condition of the sexes in the water-fleas, Cladocera, and especially *Daphnia*

and related genera. During the year in review, the work with those individuals which show an intergrading or intermediate sex has been developed in two directions: (1) a detailed analysis of various degrees of intergrading as affecting a secondary sex character of *Daphnia longispina;* (2) the continuation of the selection experiment of the sex-intergrade strains of *Daphnia longispina.*

Analysis of degrees of sex intergradedness.—As has been said in previous reports, Dr. Banta finds that the sex-intergrades are not gynandromorphs in that they are not sexual mosaics, but that in the intergrades the male and female influences are blended to various degrees in the different parts of the body, as revealed by the several secondary sex-characters. A careful study of a secondary sex-character, the first leg, has shown clearly that this interpretation is correct and that there is an almost endless variety of conditions of sexual significance in this complicated appendage, which may exist in any condition between that of the fully developed male and that of the fully developed female. This first leg in the normal female has the following simpler salient features: (1) only a single flagellum-like terminal filament to the No. 2 element, which element does not possess a hook nor have a swollen hairy base; (2) further, this appendage in the normal female has its third element terminated by three filaments. In the male, on the other hand, (1) the second element has two terminal filaments and has a large, swollen base coarsely hairy on one side, from which is developed a relatively large stout hook almost as long as the remainder of the element, and moreover (2) the third element is terminated by four filaments. Between these two conditions, that typical for the normal female and that typical for the normal male, there is every conceivable intermediate condition of development. These intermediate conditions of development may be thought of as the results of the various degrees of female and male influences operative in different individual cases and in different parts of the same intergrade individual; *e.g.*, it is of interest to note that the two legs of the same pair in the same individual daphnid may differ slightly or largely in the degree of femaleness and maleness revealed in their morphological structure. One appendage may be normally female, while its mate is slightly or largely male in character.

Further, the degree of femaleness and maleness of one or both of the first legs may be quite unlike the degree of maleness and femaleness of the other secondary sex-characters of the same individual. However, it is true that if a certain secondary character is highly male (or female), the other secondary sex-characters are likely to be male (or female) to a somewhat similar degree. But, on the whole, the correlation in degree of maleness (or femaleness) between the different secondary sex-characters in an individual is not very large and in many cases not even apparent.

The following tabular statement suggests something of a typical series of sex conditions among the sex-intergrade stock. It is merely a stereotyped outline, however, and it should be remembered that in the vast majority of individuals no such regular and coincidental gradation of secondary sex-characters occurs, *i.e.*, in this tabular outline approximately the same intermediate condition of maleness and femaleness is assumed for every character of each individual of the series, while as a matter of fact the correlation in the degree of maleness and femaleness of the different secondary sex-characters of the same individual is frequently very low or even negligible.

TABLE 4.—*Typical series of sex-intergrades. Characters of first leg of sex-intergrades and of normal individuals of Daphnia longispina.*

	Second element.				Third element. No. of filaments.
	No. of filaments.	Base.	Hairs.	Hook.	
I. Normal ♀.	1	Unswollen	None	None	3
II. Intergrade.	1 or 2	Slightly enlarged.	Few or none.	No trace	3
III. Intergrade.	2	Swollen	Few	Do	3
IV. Intergrade.	2	More swollen	Many	No trace or slight trace.	3 or 4
V. Intergrade.	2	Do	Do	Slight disturbance of contour, indicating position of hook.	3 or 4
VI. Intergrade.	2	Do	Do	Larger rudiment of hook.	4
VII. Intergrade.	2	Do	Do	A swollen, curved, irregular protuberance representing hook.	4
VIII. Intergrade.	2	Do	Do	Imperfect, usually 2-jointed, hook.	4
IX. Intergrade.	2	Do	Do	Imperfect but stout, fairly regular hook.	4
X. Normal ♂.	2	Do	Do	Perfect unjointed hook.	4

Selection in intergrade stock.—It was noticed that the sex intergrades of *Simocephalus vetulus* and *Daphnia longispina* showed a certain amount of relationship between the degree of maleness of a mother and the degree of maleness among her young. This suggested the possibility of obtaining an effect of selection by using as a basis for selection the degree of intergradeness among sibs in the same strain. Selection was begun with 6 strains of the same line of *Daphnia longispina.* These 6 strains had originated from 6 of the 8 young of a single brood of one of the original sex-intergrade mothers of this species. Three of these strains were selected toward normal femaleness and three toward intergradeness, the purpose being to make these as divergent as possible.

Selection was begun early in December 1917, and has been continued without interruption since, covering from 34 to 40 generations in the different strains. The data for only the last 16 generations of this

selection have been summarized. The summaries of the data indicate that there is an effect of selection. The strains (1, 4, and 6) selected to become more intergrade probably have not become more intergrade, but of the three strains (3, 5, and 8) selected to become more nearly normal-female-producing, two have become markedly less intergrade than they formerly were (in fact, almost exclusively normal-female-producing) and markedly less intergrade than the three strains selected for increasing the intergrade characters. One of the strains (8) selected to become less intergrade has not made progress in the desired direction during the past 16 generations (the only period for which the data have been summarized), though it had apparently done so during the 21 earlier generations of selection. A return selection is rendered extremely desirable and is to be undertaken as soon as the lines now being utilized are disposed of.

SEX-RATIO IN MAN.

Some years ago, Professor Raymond Pearl tested a view that has had some scientific currency, that hybrid matings tend to produce an excess of male offspring. He utilized for the purpose a record of the sex of offspring of matings in Argentina between native-born stock and those between immigrants from different countries. Dr. Little has tried to secure more extensive material and has been making use of the records of lying-in hospitals in the city of New York. A detailed study has been made, with the assistance of Miss Beatrice W. Johnson, of the records of the Sloane Maternity Hospital of New York City. The purpose was to compare the sex-ratio in the progeny of various types of racial matings. Matings in which both parents were from European (Caucasian) races were chosen. For the purpose of this study the term *race* is used in the sense of a biological center of more or less inbreeding. Thus, generally speaking, a mating of two Irish parents is a type of closer inbreeding than a mating in which one parent is Irish and the other Italian. Then a comparison between two such types of matings has been made. The races used were as follows: English, Irish, Scotch, German, Austrian, Russian, Italian, and Greek. These were tabulated in two main groups: (*a*) those matings in which both parents came from the same race, and (*b*) those in which the parents were from different races. While much information still remains to be gathered from the data, that part which concerns the ratio of the sexes among the offspring (including stillbirths) has been tabulated, with the results shown in table 5.

Several facts stand out as of general interest. Three of them resemble each other so closely as to suggest that a single explanation may properly include them all. These are: (1) the excess of male progeny found in the normal "pure" racial matings; (2) the significantly greater excess of males found in offspring of the "hybrid"

matings; and finally, (3) the great excess in pure matings of males among children of the first birth as compared with the later births, contrasted with the steady excess of males in hybrid matings.

TABLE 5.—*Sex ratio (male÷female) and proportion of stillbirths in pure and hybrid human matings.*

	"Pure" matings.	"Hybrid" matings.	Remarks.
Sex ratio (M÷F).			
Total births	5,753	1,305	Difference, 15.29 ± 2.26
Males	2,964	716	(6.76 times its probable
Females	2,789	589	error).
Ratio	106.27±0.95	121.56±2.06	
Percentage of still-births occurring in the two types of matings.			
Total births	5,753	1,305	Difference, 2.21 ± 0.42
Born dead	355	52	(5.26 times its probable
Percentage born dead	6.19±0.19	3.98±0.37	error).
First births:			
Total individuals	2,547	572	
Sex ratio	117.88±145	111.85±2.79	
All other births:			
Total individuals	3,206	733	
Sex ratio	97.90±1.18	129.75±2.86	
Difference between first and all other births.	19.98±1.97 (10.68 ×P.E.)	17.90±3.99 (4.5×P.E.)	

These facts are all explicable on the hypothesis that the male-forming sperm are less likely to be eliminated, because they are less able to carry genetic factors which might produce physiological incompatibility either during their intra-uterine journey or after fertilization, than are the female-producing sperm with their larger amount of foreign chromatin. Within "pure" races, the uterine secretions might at first eliminate sperm more easily and more specifically than they could later on; but the hybrids, in which there was a greater degree of difference between male and female gametes, might retain their eliminatory ability either for a longer time or even permanently. This would result in a great excess of male offspring from first matings within the "pure" races, and the continued excess of males among the racial hybrids.

The relatively smaller number of stillbirths in hybrids as compared with "pure" races is an interesting fact. At first it appears that because of the large number of cases of venereal disease involved, stillbirths are poor material for genetic analysis. But inasmuch as the result of the infection and not its occurrence is the matter of biological interest, it is entirely probable that truly genetic and biological factors underlie and determine whether a fetus infected with venereal disease shall or shall not die. The biological and genetic basis of factors con-

trolling the size of fetal head, width of pelvis, etc., is easier to admit. At all events, the genetic factors involved must be hypostatic in nature, and in this way the likelihood of the lethal RR combination being formed is greater in matings within the race than it is in matings outside of the race, where possibly an entirely different complex would exist. The work is being continued.

SEX IN MUCORS.

The work on sexuality of the mucors has been resumed by Dr. Blakeslee and zygospores hitherto unreported have been discovered, as well as a number of new forms. The investigations, however, have not been carried far enough to warrant an extended report. Attention has been called in earlier volumes, especially in Year Book No. 12, to the relative simplicity of vegetative structure in the mucors, their ease of cultivation, and the fact that the two sexes apparently contribute equal masses of protoplasm to the developing offspring. These investigations are especially adapted to biochemical investigation in the problems of sex, and these can properly be made only with the aid of a biochemist.

THE INHERITANCE OF GERMINAL PECULIARITIES.

FLOWERING PLANTS.

The genetical work on flowering plants has been seriously interrupted by the war. Our gardener, Mr. Billings T. Avery, jr., who had been identified with Dr. Blakeslee's work for many years, both in the Connecticut Agricultural College and here, died in service in France, and there has been no one else with the detailed knowledge of the strains who has been able to carry them forward with the same success based on knowledge. Since the war, a satisfactory personnel has been built up, and the prospect is good for a large development of this branch of the work.

The report of this department in Year Book No. 17, for 1918, told on page 114 of Dr. Blakeslee's plans for developing the adzuki bean as a war measure, undertaken at the request of the National Research Council. He secured the cooperation of some other breeding-stations for the development of this species. From our plots over 4 tons of adzuki beans were raised as a by-product of the experiments, and these were sold at a nominal rate to a nearby State hospital. The reports from other experiment stations on the productivity of this species were not especially favorable, due apparently to the relatively new though destructive "mosaic" disease of shelled beans. We have therefore cut down our work with the adzukis for the present and are testing out the different lines to discover, if possible, immune races before attempting further breeding with them.

Of the yellow daisies (*Rudbeckia*) we have plants growing from crosses made by Mr. Avery before he entered the service. The in-

vestigation of the inheritance of green cones and of doubling is being continued by Dr. Blakeslee. In view of the technical difficulties of hybridization, the decrease of vigor, and the increase of intersterility due to inbreeding, and on account of the loss of the special knowledge and technical skill for this work which followed the death of Mr. Avery, it seems desirable to discontinue for the most part further work with these forms.

In the portulacas, Dr. Blakeslee is carrying out further experiments with the dwarf mutation, which has been shown to be a Mendelian recessive, and with the reverting normal branches which they occasionally produce, which have been shown to be heterozygous dominants. An attempt is being made to alter the proportion of reverting branches by external stimuli. A number of vegetative mutations have also been found in flower colors, recessives mutating to dominants. The portulacas show a wide range of color in their flowers and give an opportunity to study color inheritance in this species, which is being availed of. Thus the portulacas reveal again that extraordinary richness in biotypes of plant species which Dr. George H. Shull years ago demonstrated at this station in the case of the wild shepherd's purse, a species which was commonly regarded by botanists as a unique representative of the genus in America.

Research on the variability in the jimson weed (*Datura*) is being resumed. The following mutants have been studied and named: Globe, Round-leaf Globe, Cocklebur, Poinsettia, Buckling, Sugarloaf, Polycarpic, Microcarpic, Ilex, Glossy, Rolled, and New Species. In addition, a number of new mutants as yet unnamed have been discovered and are being investigated. In one of the mutants an aberrant color ratio has occurred.

Of the cross between a weeping and an erect mulberry, the F_2 generation in the field is ready to be recorded. The weeping character appears to be a simple Mendelian recessive. Some of the F_1 plants which were last season recorded as male, this season produced both male and female flowers. Not all the F_1 plants were in flower, but in another season it should be possible to obtain sex-ratios in the F_1 generation.

In poplars we obtained last spring flowers from F_1 plants of a cross between an erect and a weeping aspen and have a few F_2 seedlings now in the nursery.

This summer, flowers were produced in F_1 plants of a cross between the purple-leaved variety of the common barberry and the form extensively used for low hedges (*Berberis thunbergii*). The former is a spreader of the wheat rust and is legislated against in many States, but the latter is immune. It is possible that a tall immune race eventually may be produced from the cross between these two species.

TETRACOTYLEDONOUS BEANS.

Dr. J. Arthur Harris has continued his investigation on variation, correlation, and selective death-rate of garden beans, especially those which have three or four cotyledons. A detailed study of the vascular anatomy of such seedlings, which has been carried on in the last three years with the collaboration of Dr. E. W. Sinnott and Dr. John Y. Pennypacker, will shortly be ready for publication.

HEREDITY OF COLOR IN DOGS.

A study has been made of data derived from the studbooks of the American Kennel Club to get at the inheritance of color in three breeds of dogs—Great Danes, Dachshunds, and Pomeranians; and a paper based on the data on Great Danes, written by Miss E. Elizabeth Jones, who has collaborated with Dr. C. C. Little in this work, is now in press. The following color-factors, apparently Mendelian in nature, have been demonstrated:

(1) *H*, a factor for "harlequin" (white) spotting, epistatic to its allelomorph *h*, the factor for solid-colored coat.

(2) *D*, a factor for intensity of pigmentation allelomorphic to *d*, producing dilute coat pigmentation.

(3) A triple allelomorph series of which the members are in order of dominance: *E*, a factor for extension of black pigment to the whole coat; E', a factor for partial restriction of black pigment, producing "brindle" or "tigered" pattern, and e', a factor producing the "fawn" coat-pattern, in which black is confined to the muzzle, face, and feet.

(4) *S*, a factor for self or white coat, allelomorphic to *s*, a factor producing a white chest or foot spot.

CROSSING OVER AND NON-DISJUNCTION IN SEX-LINKED TRAITS IN CATS, DOVES, AND CANARIES.

Dr. Little has reviewed the available literature to determine how completely the facts of inheritance in cats, doves, and canaries agree with the hypotheses of crossing over and non-disjunction advanced by various investigators to explain the occurrence of exceptional color classes in these animals.

In cats it was found that the exceptional color varieties were of two distinct sorts: (1) those which involved merely the appearance of an entirely normal and common color variety in a cross in which it was not expected, and (2) tortoise-shell males, which are an extremely rare variety, usually sterile, appearing irregularly, and, when they are fertile, breeding as yellows.

The exceptions in doves and canaries fall in the first of the two categories. To explain this first category, "crossing over" and "non-disjunction" meet serious difficulties, in that they predicate the appearance of color classes not yet observed, or interchange of genes

between the X and Y chromosomes in the heterozygous sex and, in the case of non-disjunction, sterility, which is also, as yet, unobserved.

To explain these cases, therefore, it is suggested that in certain rare individuals factorial changes from one allelomorph to another take place as follows:

In cats, from sex-linked factor Y, for the restriction of black pigment, to factor y, for the extension of black pigment to these regions.

In doves, from sex-linked factor w, for white plumage, to factor W, for colored plumage.

In canaries, from sex-linked factor p, for pink eye-color, to factor P, for dark eye-color.

To explain the second category, it is suggested that non-disjunction of the X chromosome, resulting in certain "males" which are X instead of XY in formula, is involved. Sterile tortoise-shell male cats are supposed to be animals of the constitution X, showing a peculiar mosaic distribution of black and yellow color. Similarly, the still rare fertile tortoise-shell males are considered as the result of secondary non-disjunction. These hypotheses are tentative and have been advanced by Dr. Little for consideration and experimental test.

HEREDITY IN SHEEP, MICE, AND POULTRY.

The experiments on heredity of twinning and multinippling in sheep were continued at the station. There were 30 lambs born from 17 mothers, being a proportion of 1.8 lambs per mother, as contrasted with 1.6 for 1917 and 2.2 for 1916. The cooperative sheep experiment with the New Hampshire Sheep Experiment Station is being continued.

Progress is being made with the poultry strains. During the year 109 chicks were hatched, mostly of the New Buff and Silky strains.

Dr. C. C. Little, who has been in part assisted by Mr. L. C. Strong, a graduate of Columbia University, has worked on an operative technique for ovarian transplantation in 1-day and 2-day old mice, in a series of over 300 operations. From this material it is hoped that evidence relating to the effect of the foster-mother on heredity of susceptibility to tumors, spotting, size, etc., will be secured. Mr. Strong's work was chiefly making operations upon older mice, with the view of continuing his work at Columbia University.

Mr. Reginald G. Harris, cooperating with Dr. Little, has measured skull and size inheritance of crosses in mice. Results of this will be included in the paper on the characteristics of mice which is now being prepared for publication. Dr. Little has also collected a series of over 500 mice in order to study the effect of age of transplantation to susceptibility to tumor. These animals are now under observation. Dr. Little proposes to continue this work as a control to the ovarian

transplantation work and to gain information as to the nature and effects of tumor growth.

During the summer, Dr. George B. Jenkins, of the Department of Embryology, Carnegie Institution of Washington, made preliminary studies of rumplessness, polydactylism, and abnormal plumage of Rumpless and Silky strains of poultry at this Station.

EXPERIMENTAL PRODUCTION OF VARIATIONS.

EFFECT OF CAVE CONDITIONS.

The experiment of comparing the effect of cave forms reared in the light and epigeal forms reared in caves, with the corresponding variations of these in their original habitat, is being continued by Dr. A. M. Banta. During the year he made successful collections in caves in the middle West, and we have now more cave material than at any previous time. The amount of material of most of the more readily breeding species is satisfactorily large.

PHYSIOLOGY OF REPRODUCTION.

BIOMETRIC STUDIES OF EGG PRODUCTION.

Dr. Harris has continued his statistical investigations into the physiology of egg production, with special reference to the prediction of egg production from short periods of observation. These are made in cooperation with three of the agricultural experiment stations.

OTHER INVESTIGATIONS.

CONTROL OF PROTEIN PRODUCTION IN EGG-WHITE BY QUININE.

Riddle and Anderson had already shown that the amount of the nitrogen-containing substance (protein) in egg-white was reduced under quinine. It remained to determine whether the reduction in weight implied also an actual and absolute reduction in nitrogen, or whether the reduction occurred in non-nitrogenous associates of the protein. This work was chiefly carried on during the past year by Dr. Ellinor H. Behre. An actual reduction of the nitrogen element has been found. This work has now been brought to a termination by Drs. Riddle and Behre. Their conclusions are as follows:

"Fresh-laid dove eggs contain about 12 per cent nitrogen per gram of solids.

"The data of Riddle and Anderson on the reduction of egg size and yolk size under quinine treatment are further corroborated by the records of 6 of 7 birds retested—egg size and yolk size are decreased during dosage and increased after dosage is discontinued.

"The normal quantity of (a more dilute) albumen is restored quickly after discontinuance of dosage.

"Less albumen is produced during dosage than before. Relatively more (of a more dilute) albumen is produced after dosage is discontinued than during dosage.

"The loss of weight or amount of albumen under quinine consists in (*a*) a loss of total substance, and (*b*) a disproportionate loss of solids.

"The loss of solids is accompanied by a loss of nitrogen. When the amount of albumen is later increased, in the after-dosage periods, the nitrogen does not increase in full proportion. The percentage of water remains high in albumen produced in these after-dosage periods.

"It seems clear that dosage of ring-doves with quinine sulphate causes less than the normal amount of nitrogen to be released by the albumen-secreting gland of the oviduct during the secretion of egg albumen."

CHEMISTRY OF BRAINS OF ATAXIC PIGEONS.

Dr. Oscar Riddle, in collaboration with Miss Mathilde L. Koch, of the Psychiatric Institute of the New York State Hospitals, has concluded a second study of the chemical constitution of the brains (cerebrums), analyzed separately from the cerebellums and medullas, of the strain of ataxic pigeons which has been developed in our collection. The conclusions drawn from the study are as follows:

"(1) The brains of birds which have lost a very large amount of the normal control of the voluntary movements (ataxia) show deviations from the normal brain in size and in chemical composition. These deviations are more pronounced in the cerebellum.

"(2) The brains of the ataxics are smaller. The cerebrums are either not reduced or are reduced in very small amount. The cerebellums and medullas (weighed together) are certainly reduced in size.

"(3) Eight analyses were made of anterior and posterior parts of the brain. Four of these were from ataxic and four from normal birds. The chemical changes found are more definite and pronounced in the cerebellums and medullas than in the cerebrums. The results support our previous conclusion that the differences 'suggest a chemical under-differentiation or immaturity of the ataxic brains.'

"(4) The pigeon cerebrum and cerebellum strongly contrast with the human cerebrum and cerebellum in the distribution of the several chemical constituents.

"(5) Entire brains of very young and of very old birds were analyzed. Data for the chemical changes in the brain which accompany age have been obtained for a series of ages in the pigeon. Examination of this more extensive 'age series' of pigeon brains has enabled us to evaluate much better than in our previous work the relation borne by the various chemical fractions to age.

"(6) The significance of the results obtained in the present and former series of analyses has been reviewed. The evidence warrants the conclusion that chemical differentiation does not proceed as rapidly in the brain, and more particularly in the cerebellum, of ataxic birds as in the brain of normal birds.

"More than a year ago several of these ataxic birds were sent to the Neurological Laboratory of the University of Chicago, where Dr. T. Hoshino has made a very extensive neurological study of the ataxic brains. His study is now complete and will be published simultaneously with our second paper on the chemistry of the brains."

VEGETABLE SAPS; OSMOTIC CONCENTRATION.

These studies, conducted primarily by Dr. Harris, have been outlined in considerable detail in preceding Year Books. The time available for these studies during the current year has been chiefly devoted to field work, but a discussion of the osmotic concentration of phanerogamic epiphytes, based on studies in Jamaica and in subtropical Florida, has been published. In this it has been shown that the concentration of the tissue fluids of epiphytic Bromeliaceæ, Piperaceæ, and Gesneraceæ is far lower than that of terrestrial vegetation. Furthermore, in the Bromeliaceæ, Orchidaceæ, and Piperaceæ the concentration of the species of the Jamaican rain-forest is lower than that of those found in the hammocks of subtropical Florida.

Two periods have been devoted to work in the field. The first covered the months of January, February, and March, which were spent in the mainland swamps and on the Gulf Keys of the west coast of Florida. The second covered the months of July and August, which were devoted to work along the Atlantic seaboard from the mouth of the Chesapeake to Biscayne Bay. These operations were carried out, in cooperation with the Department of Botanical Research, on a small yacht kindly placed at Dr. Harris's disposal by a friend. Mr. John V. Lawrence and Mr. M. C. E. Hauke, of the University of Chicago, took part in the operations along the Atlantic coast. Over 1,000 determinations of osmotic concentration were made by the cryoscopic method in these two field operations, but the data are not yet organized for discussion.

COOPERATIVE WORK ON HUMAN NUTRITION.

During the year Dr. Harris has published jointly with Dr. Francis G. Benedict, Director of the Nutrition Laboratory of the Institution, a "Biometric Study of Basal Metabolism in Man." This book is a compendium of statistical information, not only for the student of nutrition, but also for the anthropologist. With the assistance of his biometric assistants, Mr. Harris has worked out numerous correlations between age and stature, age and weight, weight and body-surface, weight and pulse-rate, weight and heat production, and many other elements involved in modern calorimetry. These correlations are worked out for athletes, for men in general, for women, for infants, and comparisons are made for diverse races. Some of the results of the study are to demonstrate practically no relationship between basal or normal pulse-rate and body-weight in adults, or between pulse-rate and stature. The larger gaseous exchange is associated with a more rapid pulse-rate, and the same is true of more rapid heat production. There is a close relation between gaseous exchange and body-weight and between total heat production and body-weight. It appears that throughout the whole range of adult life the heat production of in-

dividuals decreases with age. The statistical analysis shows that the body-surface law, according to which the heat production of an organism is proportional to its superficial area, is not strictly valid, but the basal metabolism in men is, on the average, higher than in women, and the actual heat production in men is higher than in women, even when the difference in physical make-up is taken into account; but no special difference is obtained in infants of the two sexes.

BIOMETRIC MISCELLANY.

Dr. Harris has undertaken, with the aid of his computing force, to make certain statistical studies on variation, correlation, and probable error on plot tests in cooperation with the Office of Western Irrigation Agriculture and the Office of Dry Land Farming of the United States Department of Agriculture.

EUGENICS RECORD OFFICE.*

C. B. DAVENPORT, DIRECTOR.

STAFF.

During the year ending September 1, 1919, the work of the Eugenics Record Office was seriously interrupted by the war. The extensive investigations of Captain A. H. Estabrook into the great family of Ishmaelites of Indiana and adjacent States have not been continued, owing to the fact that Dr. Estabrook remained, up to the time of report, in the United States Army in the psychological, and later in the reconstruction, service. Dr. Wilhelmine E. Key left March 1 to undertake the organization of a State girls' industrial school near East Lyme, Connecticut. Despite these limitations, progress has been made in several matters.

HEREDITY IN ARISTOGENIC FAMILIES.

First may be mentioned the work of Professor Howard J. Banker, who has for some years been engaged in a study as far removed as feasible from that of the defective stocks in which most of our studies have been made. No excuse or apology is necessary for having, hitherto, devoted the energies of the Office so largely to the cacogenic side. First of all, social needs seemed more pressing in this line than any other. Secondly, this aspect of eugenics brought us into close relations with superintendents of institutions and we thus secured the entrée into many homes and the cooperation of the State in the expense of the investigation.

It is an unfortunate result, however, of laying too much emphasis on this aspect of eugenics, that the term has come to have so largely a cacogenic connotation. To this situation the investigations of Dr. Banker will, it is believed, serve as a corrective. The characters that are popularly called "normal" are as clearly hereditary as any others; indeed, the very fact that they are so common in the race that they are taken for granted is the best evidence that they form the basal heritage of the race. As Doctor Banker says:

"The study of human heredity can never be complete, or even satisfactory, until these 'normal' traits are compiled and classified and their distribution through families and races are accurately described. But there are few accumulations of data on this phase of the general subject. The physician does not record the 'normal' reactions of his patient; they are assumed. 'Normal' individuals have not been segregated in institutions and had their behavior and reactions keenly observed, accurately recorded, and scientifically classified. Here, then, is an important and extensive field for observation which must be explored in order to lay a real foundation for all studies in heredity. The fact that the progress of civilization has developed no natural

*Situated at Cold Spring Harbor, Long Island, New York.

facilities for the accumulation of such data renders it all the more important that the work should be inaugurated and prosecuted persistently, to this specific end, through generations of time, by some suitably organized institution or institutions.

"There is one part of our social organization in which the normal individual might be studied and accurate records accumulated with the fullness and value shown in many of our institutions for defectives. That is the public-school system, from the kindergarten to the college. As yet, no attempt to utilize these institutions, in any comprehensive way, for the accumulation of complete and systematic records has been made.

"The present and past records of the schools, while often employed to draw fine quantitative distinctions in the awarding of prizes and determining rank in scholarship, are, nevertheless, very imperfect, unstandardized, and as a rule of much less value than they should be. College records should be better. Harvard University probably possesses the most complete and continuous records extending over the longest period of time of any institution in the country. Advantage was taken of this fact to utilize these records, as far as possible, and supplement them by a study of the family histories of the individuals represented. As was to be expected, these families are prevailingly normal and efficient, with a tendency, apparently, to produce superior, rather than inferior, individuals. A remarkable, though not wholly unexpected, result that has developed is the fact that a large proportion of these selected old Harvard families are so intermarried that, as the study is extended, most of them tend to form part of a continuous family network."

During the past year and a half Dr. Banker has been almost wholly engaged in compiling biographical data of the individuals of one section of this network. This has now included incomplete studies of over 3,000 individuals, of whom nearly 500 are college graduates. It should be remembered that probably half of the total number of individuals are females, for whom, except in the case of a few of the latest generation, there are no college records. Approximately 1,000 letter-size pages of notes and citations from more than 400 works have been made, while probably more than four or five times that number of works have been consulted. As near as can be judged, the network has been only about two-thirds covered. No attempt has yet been made to analyze these data, to which additions are still being made. "A surprisingly large amount of biographical data, more or less satisfactory, concerning the individuals of these families is to be found in various publications. If they did not all get into the colleges," says Dr. Banker, "they did get into the books and papers. Many of the most valuable items are buried in 'Reminiscences' and 'Autobiographies' of their friends, or enemies, and other works not ostensibly concerning the person sought and, hence, not discoverable through the usual library indexes."

Meantime, with the work of analyzing the inheritance of the traits of successful men must go hand-in-hand the analysis of personality and a consideration of the "springs of conduct." A little attention to this matter brings out strongly the fundamental result that it gives us

pleasure to do those things for the doing of which well we have special gifts. Attempts to do things for which we have no natural aptitude are distasteful; but we like to do the things that we can do well; and we can do well, after a little training, things for the doing of which we have natural aptitudes. So we like to do the things for which we have natural aptitudes.

These conclusions are supported by the work on "Naval Officers, their Heredity and Development," prepared by the Director, with the assistance of Miss Mary F. Scudder, and published by the Institution. This study shows that naval fighters are chiefly hyperkinetics (overactive). In their youth they were nomadic, thalassophilic, adventurous. Other naval officers were such because they were great strategists (like St. Vincent), administrators (like Stockton), explorers (like Sir John Franklin), and adventurers (like William B. Cushing), Each type has its prevailing temperamental and intellectual equipment. Each officer, as a boy, gave promise of his adult performance. One of the most widespread traits among naval officers is love of the sea (thalassophilia). This is an inherited racial trait, a fundamental instinct. In inheritance it acts like a recessive that is also sex-limited, so that it shows itself almost exclusively in males. Another trait of fighting naval officers is, as just stated, hyperkinesis, a dominant trait. Still a third is nomadism, a sex-linked trait. Thus, the total inheritance of great naval fighters and explorers is complex.

INBRED COMMUNITIES.

Another investigation that is under way is that of certain isolated island communities, to learn the results of inbreeding in those communities. Some years ago, Miss Mary M. Sturges spent 18 months, at intervals, in one such locality and 6 months in another for comparison with the first.

"In the first island a fairly complete genealogy was obtained of the descendants of twelve children from a marriage dating 1800, with ancestral and collateral lines so determined that relationships are quite accurately known. A rougher, although fair, genealogy was obtained in the second island, and an endeavor was made to furnish each with a good historic and descriptive setting.

"Since consanguineous marriages subsequent to 1825 have formed 48 per cent (first-cousin marriage 11 per cent) of all, so many ancestors were common that direct and collateral branches could be unusually well known. Thus, aside from a useful addition to our knowledge of the sociological elements of isolation and inbreeding, the material affords by comparison of branches and location of traits in inheritance a background for such intensive work as may seem desirable. By means of such comparison and one rough census of 6 of the 12 complete branches (2 parallel first-cousin marriages, 4 parallel marriages of a set of brothers with a set of sisters), certain traits have been roughly located and the two months this summer have been spent in tabulating them; the incidence of left-handedness; red hair; albinism, asthma, hayfever, eczema, and angioneurotic edema; twinning; congenital anomalies, single or

apparently linked in inheritance; nervous instability, best recognized as epilepsy in one strain, insanity in another, and feeble-mindedness in a third—such form a promising field if careful, intensive work be available for a sufficient time upon one well-known genealogy."

DEFECTS IN DRAFTED MEN.

Most of the time of the Director was spent in the Surgeon General's Office, Washington, on work akin to that of the Eugenics Record Office, namely, the distribution of defects found in drafted men and the physical measurements of such men. Four reports were projected and, of these, one is published (June 1919); one is in the hands of the printer; a third is over half done, and material for the fourth, the proportions of soldiers of different races and sizes, is being collected.

The first of these reports, published in collaboration with Lieut. Col. A. G. Love, is entitled "Physical Examination of the First Million Draft Recruits: Methods and Results," and shows clearly that the varying proportion of defects detected at camps in accepted recruits from various States depends upon sundry causes, in part social, in part biological. The vast number of weak feet found was one of the features of the report. About one-fifth of all recruits showed weak feet, and this defect was commoner in recruits from the cities than from rural districts. This result indicates that the human foot is poorly adapted to the demands made upon it by modern civilized life. Even recognizing that much of the foot defect is due to wearing fashionable foot-gear (so that it is commoner in the Northern than the Southern States), yet the fact that it is common in rural districts, and especially where the population is of tall stature and heavy, indicates that the relatively recent adjustment to plantigrade locomotion of a foot that in the ancestors served for arboreal locomotion is far from meeting satisfactorily the requirements of our social organization. Again, hernia, more or less developed, was found in 3.5 per cent of the recruits. Here, again, there is evidence of a widespread, imperfect adaptation of the muscles and fascia of the inguinal region to carry the load and resist the pressures that accompany man's operations in an erect posture. Again, varicose veins and varicocele were found in great numbers, especially among tall recruits, indicating that the walls of veins of the legs and lower trunk are not always perfectly adjusted to the new hydrostatic problems introduced by man's erect position. Probably an important part of the "mental deficiency" is a heritage from neolithic and paleolithic man.

It is probable that part of these disharmonies between posture and size, on the one hand, and ability of parts to meet demands made on them is due to the hybridization between short and tall races that has been going on in this country, by which developmental tendencies adapted to small races have come to be associated with tendency to development of great size of body.

On the social side, there were about 3.3 per cent of recruits with venereal disease; but much more among the colored recruits than the white. Absence of fingers, arms, and legs were most frequent in regions of saw-mills, of cotton-mills in the South, and in cities largely made up of workers in railroad shops and of other present or former railroad employees.

The problem of goiter was brought out vividly when two great goiter centers were revealed—one about the Great Lakes and the other in the extreme Northwest.

The excess of pulmonary tuberculosis from the desert sanitoria States of the West revealed the great extent of the migration thither of the tuberculous.

The result of the draft was not such as to justify pessimism as to the national physique. Defects were found in less than half of the drafted men; and it is fair to conclude that in less than 8 per cent of the men was the disability of such a nature as to handicap the man in an important way for civil duties.

Since the remainder of the statistical work on the physique of the men of military age is not yet published, it will not be discussed here. It is believed that the experience gained by your Director in studying this data will be of no little use in further developing the work of the Eugenics Record Office.

FIELD WORK.

The work of Dr. Elizabeth C. Muncey during the year has been of a varied sort. On the one hand, she has secured extensive genealogical data on military men. For this purpose she has utilized the Library of Congress. She has also done some field work on twin-producing families and on families showing other traits which occurred in the territory traversed by her. Reports on all of her researches have been deposited at the Office.

STERILIZATION LAWS.

Dr. H. H. Laughlin, superintendent of the Office, has prepared for publication a work on the legal and legislative aspects of eugenical sterilization in the United States.

STATISTICAL STUDY OF STATE INSTITUTIONS.

The Bureau of the Census reports that the statistical study of State institutions for the socially inadequate, prepared during the years 1915 to 1917, the publication of which was delayed on account of the war, is now in press. This work gives a short historical account and, in detail, a statistical analysis of the accommodations, the movement of the population, and the administrative and maintenance expenditures of each of the 634 State and National institutions for the several types of the socially inadequate. It will appear under the title "A Statistical Directory of State Institutions for the Care of Defective, Dependent, and Delinquent Classes."

ELIMINATION OF MONGREL BLOOD BY OUT-BREEDING.

Statistical studies on the relation between the number of chromosomes characteristic of the species and the rate of the elimination of mongrel blood by the pure-sire system of breeding (on the assumption of no "crossing-over") are being made by Dr. Laughlin. A preliminary report of this work was given before the Society for Experimental Biology and Medicine on May 24, 1919.

ARCHIVES.

A large and important part of the current activities of the Office is devoted to the securing, filing, and indexing of data to be available for special studies.

Schedules.—For the purpose of the collection and recording of data, schedules are prepared and are distributed to collaborators or held in the office, as the case may require. Three of these schedules were printed during the year:

(1) Schedule for the cooperative use of genealogists and biographers. This is a 4-page, 5 by 8 inch folder. This was issued in November 1918, and is designed for the use of genealogists and biographers (*a*) in listing the families and individuals being studied, and (*b*) describing the forms and methods used in securing, recording, and preserving biographical and family-history data. Also (*c*) it urges the desirability of recording in the usual family history and biographical studies more data descriptive of inborn physical, mental, and temperamental traits.

(2) Index of fragmentary data or abstract form. This is a single 5 by 8 inch sheet, issued March 1919. The purpose of this sheet is to facilitate the condensation and preparation for permanent filing and proper indexing of the fragmentary data which come to the attention of the office from time to time; also for abstracting from letters and other sources fragmentary data and references of eugenical import which, if preserved only in the original form, would probably ultimately be lost in the dead-files.

(3) Study of heredity of weight, a single 5 by 8 sheet, issued April 1919. This schedule is patterned after a similar form on stature, which latter proved very valuable in securing pedigree records.

Clippings.—The new system of filing newspaper clippings has been installed and is developing satisfactorily. For this work 5 by 8 inch manila pockets or envelopes without flaps are provided as containers. The clippings are pasted on manila sheets which fit into these envelopes, which are then duly indexed and added to the proper file, according to whether the clippings are biographies or descriptive of special traits. 4,000 envelopes have been opened, which at present contain 4,800 sheets of biographical material and 575 of special trait descriptions.

FILER'S HAND BOOK.

New instructions for classifying, filing, and indexing.—A new scheme for classifying, filing, and indexing all records, books, and correspond-

ence of the Eugenics Record Office has been worked out and described in detail in a mimeographed pamphlet of 23 pages. These instructions provide for the three types of eugenical records—the archives, the library, and the correspondence files. The new system is based upon the experience of the past decade in classifying and indexing eugenical material. The Dewey Decimal System is incorporated into the library scheme. The plan for classifying the archives is a new one in which the different types of records are distributed among 19 files, each designated by a distinctive letter. The material within each file is classified according to the trait-book (Bulletin No. 6 of the Eugenics Record Office). The system of classifying correspondence is one devised for the particular needs of the office and, like the Dewey Decimal System for classifying books and the subject decimal classification of the War Department correspondence file, is an indefinitely expansible decimal scheme. It provides also for ample cross-references.

Additions to archives.—The care of the archives has remained in the hands of Miss Louise A. Nelson. She furnishes this summary of material added to the archives during the year, September 1, 1918, to September 1, 1919:

Index cards	74,149
Persons-index	240
Manuscript material:	
Field reports:	
Pages of description	3,648
Sheets of pedigrees	523
Individuals charted	17,310
Records of family traits	174
Family distribution of personal traits	3
Additional individual analysis cards	64
Biographies	53
Genealogies	76
Genealogical pamphlets	3
Town histories	30
Lists of genealogies	2

This report brings the total number of index cards reported up to 684,064. Since each card has space for 40 entries (though in most cases there are only 1 or 2 entries), it is certain that the entries must be much over 1,000,000 and probably nearly 2,000,000. Of special field workers' reports we have now 56,825 pages. Of the record of family traits there are on file approximately 3,000.

TRAINING COURSE.

The 1919 training course for field-workers in eugenics was in session from July 2 to August 12. There were 16 students in the course, thus bringing the total number who have been trained by this office for field-workers up to 192. The demand for competent field-investigators is greater than the supply.

JOINT-BASIS FIELD-WORKERS.

An important element of the work of the office is the introduction of eugenical field-studies as a part of the regular work of custodial institutions for the several types of the socially inadequate. This has been worked out on the joint-basis plan, whereby the Eugenics Record Office trains the worker and pays her salary and the collaborating institution provides the maintenance and traveling-expense money. Two new joint-basis field-workers have been assigned for

the year beginning October 1, 1919, as follows: (1) Virginia Rohde, 1919, to the State Hospital at Bangor, Maine; (2) Cornelia Augenstein, 1919, to the Girls' Training School at Gainesville, Texas. Owing to war conditions, the contract for a joint-basis worker made a year ago with the Central Islip State Hospital at Central Islip, New York, was discontinued in April 1919. The contract is being completed by assigning (3) Miss Dorothy Aldridge, of this year's training course, to 6 months' work at Central Islip, beginning September 1, 1919.

Custodial institutions which have introduced modern eugenical field-studies by the joint-basis plan now number 53.

VOLUNTEER COLLABORATORS.

Superintendents of institutions who have once introduced modern eugenical field-studies into their work continue to send for deposit at the Eugenics Record Office copies of family-history studies made independently by their own workers. This year special mention should be made of contributions from Dr. David F. Weeks, superintendent of the State Village for Epileptics at Skillman, New Jersey; of Dr. Fred C. Nelles, superintendent of the State School at Whittier, California; of Dr. Floyd C. Haviland, superintendent of the State Hospital at Middletown, Connecticut; of Dr. F. Kuhlman, of the Minnesota School for Feeble-Minded at Faribault, Minnesota; of Dr. Oscar E. Thompson, of the State Institution for Feeble-Minded of Eastern Pennsylvania, at Spring City, Pennsylvania; of Dr. C. A. Potter, of the Gowanda State Hospital at Collins, New York; of Dr. Chester L. Carlisle, director of the Bureau of Analysis, State Board of Charities, at Albany, New York; and of Dr. Charles S. Little, superintendent of the Letchworth Village for Epileptics at Thiells, New York. Besides these institutions, a number of eugenicists have, on their own account, been èqually generous and attentive in their collaboration. During the past year eugenical records have been contributed to the archives of the Eugenics Record Office by Professor Will S. Monroe, Montclair, New Jersey, and many others.

EUGENICS RESEARCH ASSOCIATION.

On February 18, 1919, the executive committee of the Eugenics Research Association, acting in consequence of instructions given by the association at its previous annual meeting, passed a series of resolutions seeking the cooperation of the State and National governments and organized societies and State institutions in eugenical research, and the application of practical eugenical matters.

The seventh annual meeting of the association was held at Cold Spring Harbor on June 20, 1919, under the presidency of Mr. Madison Grant. A committee was appointed for the purpose of representing the Eugenics Research Association in connection with the organization of a forthcoming international eugenics congress. The president for the year 1919–20 is Dr. Stuart Paton, of Princeton, New Jersey.

GEOPHYSICAL LABORATORY.[1]

ROBERT B. SOSMAN, ACTING DIRECTOR.

Since the date of the last annual report (October 1, 1918), the war has been brought to an end by the armistice of November 1918, and most of the Laboratory's staff has been released from war work to return to the researches interrupted in 1917.

This release could not be immediately accomplished, however, for two reasons. First, there remained in the possession of the Laboratory a considerable amount of new data, both technical and scientific, bearing on the war problems in which the staff had been engaged, which needed to be written up in form for publication. Second, there were several lines of research which by an additional few months' work could be made to yield valuable results, whereas if abandoned where they stood they would represent a complete loss of the existing experimental preparations and incomplete data.

A part of the work of the year may thus be considered as salvage work following the disturbance of conditions due to the war. The principal war work of the Laboratory was concerned with directing the manufacture of optical glass for Army and Navy instruments. The scientific and technical results of the optical-glass work are for the most part being published as a series of papers on the manufacture and properties of optical glass, of which 21 numbers have been published or are in press.[2]

A second war problem was concerned with the fixation of nitrogen for the manufacture of explosives. Experimental work on the chemistry of the so-called Bucher cyanide process and the Haber or synthetic process was begun in the summer of 1918, and had therefore not proceeded far when the war ended. A few papers on the chemistry of these processes will put on record the facts of scientific interest obtained in connection with the problems investigated.[3]

VOLCANO STUDIES.

Investigations of the phenomena of active volcanoes were begun by the Laboratory in 1911 at Kilauea, Hawaii, and reports of the work there have been included in several previous Annual Reports.[4] In 1914 the work was extended to several of the Italian volcanoes (Vesuvius, Etna, Stromboli, Vulcano), and observations thereon have been continued, though under considerable difficulties and limitations, during the war.[5]

In 1915, observations were made on the volcano of Lassen Peak, in California, which began explosive eruptions in 1914, after a period of quiescence extending back of historic records, and continued its

[1] Situated in Washington, District of Columbia.

[2] See abstracts (1), (2), (3), (13), (14), (15), (17), (19), (20), (25), (26), (27), (29), (32), (38), (39), (40), and (44), below.

[3] See abstracts (10) and (34) below. Other papers will appear later.

[4] Year Book 10, 91 (1911); 11, 99, 100 (1912); 12, 127–129 (1913); 15, 141–143 (1916); 16, 134 (1917).

[5] Year Book 16, 137–140 (1917).

activity into 1915. In 1916, although the explosive activity had died down, our work was continued on the hot springs about the base of the mountain.

The observations were followed by a year's work in the Laboratory, the results of which have been prepared for publication, but will not be in print in time to form a part of this year's report.

During the past year opportunity has been offered, through the courtesy of the National Geographic Society of Washington, to send three men to the "Valley of Ten Thousand Smokes," an extensive active fumarole region adjacent to the volcano Katmai, on the Alaska Peninsula. The recent eruption of Katmai was of the explosive type, and was on a scale hardly equaled in historic times. It was accompanied by the formation of the "Valley" referred to, in which an unusual type of fumarole activity has been going on for several years. The Laboratory furnished thermometric and gas-collecting apparatus to the National Geographic Society expeditions of 1917 and 1918, and the temperatures found were so high and the vapor composition so unusual that it was thought well to send a party this summer equipped to do a certain amount of analytical and petrographic work in the field, and to further investigate the fumarole phenomena as to temperatures and flow of gases. A considerable amount of laboratory work will be needed to supplement the observations. It is hoped that the field and laboratory work will throw much additional light on the phenomena of fumarolic and explosive volcanic activity.

The observations at Kilauea early showed the close connection that existed between the quantity of gas being given off from the lava lake and the temperature and general activity. Efforts were made to collect gases fresh from the lake and uncontaminated with air, a task by no means easy. The unexpectedly large amounts of water met with in the gases collected in 1912 interfered with the determination of the quantitative composition of the gases as a whole, by condensing in the pipes which led the gases out to the collecting-tube. The composition of the "fixed" gases could be determined, but not their relation to the water-vapor. In 1917 gas samples were obtained in which the relation of water to the other constituents could be determined. The analysis of these samples has been completed during the past year.[1]

Perhaps the most striking thing about these analyses is the wide variation in the composition of the gas samples, though collected at about the same time and under fairly constant conditions as regards the activity of the crater. It is evident that the gases are far from a state of equilibrium when they issue into the atmosphere; at the same time the elements are quite extensively oxidized, although variable amounts of unburned hydrogen, sulphur, and carbon monoxide do reach the surface. Water is always present, and in surprisingly large amounts.

[1] See abstract (35), below.

The elements present in large amounts are carbon, hydrogen, sulphur, nitrogen, and oxygen. The first three occur principally as oxides. The percentage of chlorine is usually very small, and the rare gases are often no more in amount than would be required on the assumption that the nitrogen had come in as air (entrapped in sinking crusts or carried down by fountaining, for instance).

Any extended deductions or speculations as a result of this work may well be postponed until the more recent samples of gas, collected by Dr. Jaggar under conditions selected with reference to particular lines of study of the crater, have been analyzed. This work is now under way in the Laboratory.

The simultaneous study of these gases from the synthetic side, which has been commented upon in a previous Annual Report,[1] has been interrupted by war conditions. A comprehensive discussion of the equilibria and reactions concerned must await further field and laboratory work.

THE BINARY AND TERNARY SYSTEMS OF SILICA, ALUMINA, MAGNESIA, AND LIME.

This year sees the completion of the last of the four ternary systems which can be made up from the four oxides, SiO_2, Al_2O_3, MgO, and CaO.

The system SiO_2–Al_2O_3–CaO has been commented on in previous Annual Reports.[2] The systems SiO_2–Al_2O_3–MgO and Al_2O_3–MgO–CaO have been given passing mention in previous reports, while the system SiO_2-MgO-CaO is new this year.[3] A summarized review of some of the salient facts concerning these systems may bring out some points of interest.

THE COMPOUNDS.

The binary and ternary compounds found in these four systems are as follows:

BINARY COMPOUNDS.

System.	Compound.	Ratio of oxides.	Stability at melting-point.	Mineral name.	Known forms.
SiO_2–Al_2O_3	Al_2SiO_5 or $Al_2O_3.SiO_2$	1 : 1	Stable	Sillimanite	
SiO_2–MgO	$MgSiO_3$ or $MgO.SiO_2$	1 : 1	Unstable	Enstatite	I, II, III, IV.
	Mg_2SiO_4 or $2MgO.SiO_2$	2 : 1	Stable	Forsterite	
SiO_2–CaO	$CaSiO_3$ or $CaO.SiO_2$	1 : 1	Stable	Wollastonite	α, β.
	$Ca_3Si_2O_7$ or $3CaO.2SiO_2$	3 : 2	Unstable		
	Ca_2SiO_4 or $2CaO.SiO_2$	2 : 1	Stable		α, β. β′, γ
	Ca_3SiO_5 or $3CaO.SiO_2$	3 : 1	Unstable		
Al_2O_3–MgO	$MgAl_2O_4$ or $MgO.Al_2O_3$	1 : 1	Stable	Spinel	
Al_2O_3–CaO	$Ca_3Al_{10}O_{18}$ or $3CaO.5Al_2O_3$	3 : 5	Stable		I, II.
	$CaAl_2O_4$ or $CaO.Al_2O_3$	1 : 1	Stable		
	$Ca_5Al_6O_{14}$ or $5CaO.3Al_2O_3$	5 : 3	Stable		I, II.
	$Ca_3Al_2O_6$ or $3CaO.Al_2O_3$	3 : 1	Unstable		
MgO–CaO	No compounds.				

[1] Year Book 15, 141 (1916). See also abstract (7), below.
[2] Year Book 7, 97–99 (1908); 9, 91 (1910); 13, 135–137 (1914).
[3] See abstracts (4), (23), and (24), below. Also (37), on the forms of silica.

TERNARY COMPOUNDS.

System.	Compound.	Mineral name.	Stability at melting-point.
SiO_2–Al_2O_3–MgO....	$2MgO.2Al_2O_3.5SiO_2$....................	Cordierite..	Unstable.
SiO_2–Al_2O_3–CaO.....	$CaO.Al_2O_3.2SiO_2$......................	Anorthite...	Stable
	$2CaO.Al_2O_3.SiO_2$......................	Gehlenite...	Stable
SiO_2–MgO–CaO.....	$CaO.MgO.2SiO_2$......................	Diopside....	Stable
	$CaO.MgO.SiO_2$........................	Monticellite.	Unstable.
	$2CaO.MgO.2SiO_2$.....................	Åkermanite.	Stable.
	$5CaO.2MgO.6SiO_2$....................	....	Unstable.
Al_2O_3–MgO–CaO	No compounds.		

It will be seen from the tables that most of the stable binary compounds are made up of the oxides in the simple ratios 1:1 or 2:1. Most of the unstable binary compounds, on the other hand, are made up in the proportions 3:2 or 1:3. A similar rather crude generalization holds for the ternary compounds, since the stable ternary compounds can be considered as built up from the known simple binary compounds in the simple ratio of 1:1 as follows:

Anorthite............................	$CaSiO_3.Al_2SiO_5$	(1:1)	(1:1)
Gehlenite............................	$Ca_2SiO_4.Al_2SiO_5$	(2:1)	(1:1)
Diopside............................	$CaSiO_3.MgSiO_3$	(1:1)	(1:1)
Åkermanite............................	$Ca_2SiO_4.MgSiO_3$	(2:1)	(1:1)

Two of the unstable ternary compounds, on the other hand, have the irrational-appearing ratios 2:2:5 and 5:2:6, although the third (monticellite) may be considered a 1:1 compound of the orthosilicates Ca_2SiO_4 and Mg_2SiO_4.

The regularities noted give the impression that the units of which these compounds are built are not *atoms*, but the atomic groups that we are familiar with as the *oxides*. These silicates seem to fall into the class of Werner's second and third order compounds. It is, then, clear why attempts to apply to the silicates the structural formulas and hypothetical "silicic acids" suggested by organic chemistry have accomplished so little either in predicting new facts or in rationalizing those already known. Future progress is to be expected rather from X-ray studies of the structure of these compounds, which are shown by accumulating evidence to be essentially different in character from the compounds of carbon.[1] It is not too much to expect that some of the complex silicates will prove to be geometrical rather than chemical compounds.

PHASES AND PHASE BOUNDARIES.

The boundary curves of the fields of the various primary phases in the three-component systems show certain regularities. The general direction of the boundary curves in the system SiO_2–Al_2O_3–CaO is

[1] See also abstract (45) below.

parallel to the SiO_2–Al_2O_3 side of the triangle, a fact that certainly is connected with the already familiar fact that SiO_2 and Al_2O_3 resemble each other in their chemical relations more than either resembles CaO—another way of saying that SiO_2 and Al_2O_3 are "acidic" oxides, while CaO is "basic." With this in mind we are not surprised to find that the boundary curves in the system Al_2O_3–MgO–CaO trend parallel to the MgO–CaO side; likewise that the boundary curves in the system SiO_2-MgO-CaO also trend parallel to the MgO-CaO side. In the system SiO_2–Al_2O_3–MgO, however, a definite trend of boundaries is not so marked; they tend rather to radiate from the peculiar solid-solution field that occupies the middle of the triangle.

The systems SiO_2–Al_2O_3–CaO and Al_2O_3–MgO–CaO are notably free from the complications due to solid solution. A peculiar situation arises in the system SiO_2–Al_2O_3–MgO from the fact that the only ternary compound is unstable, and is represented only in a solid-solution field whose boundaries do not include the compound. The system SiO_2–MgO–CaO, finally, is considerably complicated by the existence of solid solutions between the various binary and ternary compounds.

Inversions.

There is not space here to discuss the various polymorphic forms of the oxides and compounds, beyond remarking that there must be a fundamental connection between the inversions, both of the sluggish and the prompt-reversible types, in the silicates on the one hand and the similar inversions of the two types in silica itself on the other hand. This relation forms a problem in molecular chemistry and physics that remains for the future to solve.

Temperature Range.

The temperatures of the liquidus surfaces of these four ternary systems lie between the limits 1165° C. (the eutectic of tridymite, wollastonite, and anorthite) and 2800° C. (the melting-point of magnesia). The great bulk of the quadruple and quintuple points, however, lie within the limits 1300° C. to 1600° C.

THE OXIDES OF IRON.

The investigations of the high-temperature relations of the oxides of iron, discussed in a previous Annual Report,[1] were interrupted by war conditions, but work on the low-temperature hydrated oxides, as well as on methods for the determination of ferric and ferrous iron, has been carried forward during the year.[2] The previously existing confusion with regard to the mineral hydrated oxides of iron has been satisfactorily resolved by the microscopic and thermal study of a large amount of material, and it has become clear that only one hy-

[1] Year Book 15, 137–139 (1916).
[2] See abstracts (16), (21), (22), (30), and (42), below.

drate, $Fe_2O_3.H_2O$, has definite and reproducible properties as a crystalline mineral. It occurs, however, in two crystalline modifications, goethite and lepidocrocite.

It is characteristic of hydrated ferric oxide that it occurs quite commonly in finely fibrous crystalline forms, as well as in an "amorphous" form. In the "amorphous" form it is in a condition so fine-grained that its crystalline character—or sometimes even the fact that it possesses any crystalline character—can not be determined. In both the fibrous and amorphous forms the oxide holds variable amounts of adsorbed and capillary water. Limonite is the amorphous monohydrate having associated with it this adsorbed and capillary water; while turgite seems to be a solid solution of the crystalline monohydrate, goethite, with the anhydrous, oxide hematite, the solid solution holding in addition adsorbed and capillary water. An amorphous or crypto-crystalline hydrate having a given percentage of water may thus be either a limonite or a turgite, depending on the internal constitution of its fibers or grains.

Considerable progress has been made on the ternary system Fe_2O_3–SO_3–H_2O, which involves hematite as well as the hydrated oxides, but the work will not be in press in time for inclusion in this report.

PUBLICATIONS.

Brief reviews of the papers published by members of the Laboratory staff during the current year follow:

(1) The identification of "stones" in glass. N. L. Bowen. J. Am. Ceram. Soc., 1, 594–605 (1918). (Papers on Optical Glass, No. 4.)

The petrographic microscope is a convenient and efficient instrument for the determination of the nature and origin of "stones" or crystalline particles occurring in glàss. Stones are divided into four classes: (1) pot stones, (2) batch stones, (3) crown drops, (4) devitrification stones. These classes have distinctive features of structure and texture that are revealed by the microscope. Moreover, the crystalline phases contained in stones can be identified by a determination of their optical properties. The results of a study of stones by these methods are given in this paper.

(2) A contribution to the methods of glass analysis, with special reference to boric acid and the two oxides of arsenic. E. T. Allen and E. G. Zies. J. Am. Ceram. Soc., 1, 739–786 (1918). (Papers on Optical Glass, No. 5.)

Arsenic.—An accurate method for the separation and determination of both trivalent and pentavalent arsenic in glasses is described. (1) The separation depends on the volatilization of the trivalent arsenic as AsF_3 when the glass is heated with hydrofluoric and sulphuric acids, while the pentavalent arsenic remains in the residue. (2) The latter is determined by precipitation as sulphide which is then oxidized to arsenic acid, reduced by hydriodic acid, and titrated with a standard iodine solution. (3) The trivalent arsenic is determined by difference between the pentavalent and total arsenic. The determination was controlled by direct determination with the aid of a platinum still. (4) The total arsenic is determined by fusing the glass with sodium carbonate and niter, removing the silica and excess nitric

acid by evaporation with sulphuric acid and subsequent filtration; and finally proceeding as outlined in (2).

These methods for arsenic in glasses are generally applicable to substances in which the arsenic can be transformed into sulphide without loss, and are highly accurate.

A comparison of the iodometric method and the magnesium pyroarsenate method for arsenic in glass is made. The former has the advantage in accuracy and also in speed, except where occasional determinations are called for.

Boric acid.—For the determination of boric acid we have found that Chapin's method is very reliable and yields highly accurate results. It has been shown that in order to obtain very accurate results a "blank" must be made and the value applied as a correction to the amount of boric acid found. The correction is small and for ordinary work can be neglected. The accuracy of the method is very appreciably affected by relatively large amounts of *arsenious* acid, but not by *arsenic* acid. Boric acid can therefore be satisfactorily determined in the presence of large amounts of arsenious acid by oxidizing the solution with H_2O_2 after making it distinctly alkaline with NaOH.

Relatively large amounts of fluorides appreciably affect the accuracy of the determination, but do not seriously impair its usefulness for ordinary work.

Other determinations.—Our experience with the following cases in glass analysis is detailed: (1) the determination of the minute quantities of iron in optical glass; (2) the separation and determination of zinc; (3) the separation and determination of lead and barium when they occur together; (4) the separation of calcium or barium from relatively large quantities of aluminum occurring with almost no iron; (5) the determination in boric-acid glasses of those elements with which the boric acid interferes.

Attention is called to the universal presence of hygroscopic moisture in powdered glass samples. Some data by Mr. E. S. Shepherd on gases in glass are given.

(3) The condition of arsenic in glass and its rôle in glass-making. E. T. Allen and E. G. Zies. J. Am. Ceram. Soc., 1, 787–790 (1918). (Papers on Optical Glass, No. 6).

Analyses show that in all the glasses tested, both plate and optical glasses, the major part of the arsenic present exists in the pentavalent state, but nevertheless a portion exists in the trivalent state. It appears that arsenic trioxide is oxidized at a low temperature and the product formed is stable enough to remain until a high temperature is reached and the glass becomes fluid, when it slowly dissociates into oxygen and arsenic trioxide, both of which aid in the fining.

(4) The ternary system $CaO-MgO-SiO_2$. J. B. Ferguson and H. E. Merwin. Proc. Nat. Acad. Sci., 5, 16–18 (1919).

A brief preliminary report upon the results of an extended study of this ternary system. (See abstracts (23) and (24), below.)

(5) Silicate specific heats. Second series. Walter P. White. Am. J. Sci., 47, 1–43 (1919).

Specific heats of various forms of silica and silicates have been determined for upper temperatures from 100° to 1400°. The method was by dropping from furnaces into calorimeters. A rather unusual number of checks and precautions against error was employed, which are described in detail. Two new methods are described for determining true or atomic heats from interval heats.

On the whole, the general temperature variation of the specific heats is one depending mainly on the value of ν, the atomic vibration period, for oxygen in

combination. Several forms of silica, whose expansion is very small, and which therefore practically give values of specific heat at constant volume, C_v, show that C_v for high temperatures exceeds the theoretical value 5.96. Glasses show, in the main, a specific heat only slightly above the corresponding crystal forms, but with a tendency to increase at some rather high temperature. In several sets of polymorphic forms with sluggish inversions there were differences of about 2 per cent between the two forms, but none of these forms showed any variation in specific heat near the inversion temperature. In quartz, below the α–β inversion at 575°, the heat absorption is greater than can be accounted for even by the abnormal expansion. If such absorption, unusual change of volume, and change of crystal properties are each or all together the sign of a change of state, then quartz undergoes a gradual change of state over an interval of 400° below what is commonly called its α–β inversion. Quartz, and probably other forms of silica, exhibit what appear to be two kinds of inversion, due to different mechanisms.

Some of these facts militate against certain hypotheses which make polymorphism the resultant of polymeric or isomeric changes in the solid.

(6) Specific heat determination at higher temperatures. Walter P. White. Am. J. Sci., 47, 44–59 (1919).

This paper deals with the experimental technic of specific heat determination at temperatures up to 1400° by the "method of mixtures," and continues some earlier presentations. Detailed modifications in furnaces and in methods of transferring to the calorimeter are described. The heat losses attending the dropping of hot bodies into water proved to be surprisingly large; their prevention is probably advisable in accurate work, perhaps by the use of aneroid calorimeters.

(7) The thermal dissociation of sulfur dioxide. J. B. Ferguson. J. Am. Chem. Soc., 41, 69–72 (1919).

The degree of dissociation and the equilibrium constants for the dissociation of sulphur dioxide have been calculated from the equilibrium measurements of the reduction of sulphur dioxide by carbon monoxide and the dissociation of carbon dioxide, and the results of these calculations for a number of temperatures and pressures are given in this paper. The values obtained confirm the experimental results, which indicated that the dissociation was too slight to be directly studied by the present available methods.

(8) The determination of the compressibility of solids at high pressures. Leason H. Adams, Erskine D. Williamson, and John Johnston. J. Am. Chem. Soc., 41, 12–42 (1919).

The change in volume of a solid under the influence of pressure is rarely greater than a few parts per million for each atmosphere change of pressure. It is therefore not surprising that the measurement of the volume-change of solids as affected by pressure should offer peculiar difficulties, quite apart from those inherent in high-pressure experimentation, and that the published records contain very few measurements on the compressibility of solids under high pressures. This paper describes a method by means of which the volume-change under pressure of a solid may be determined with an accuracy of about 1 part in 10,000 of the original volume of the solid; that is, the volume-change for a range of 10,000 kg. per sq. cm. is determined with an accuracy of 10^{-8} per kg. per sq. cm. Results are presented for the metals gold, copper, silver, aluminum, zinc, tin, cadmium, lead, and bismuth; for the alloys brass and tin-bismuth eutectic; and for sodium chloride, calcium carbonate, and silica, both crystalline and amorphous. The pressure range was 2,000 to 12,000 megabars (1 megabar = 0.987 atm.). In carrying out the determina-

tion a cylinder of the solid, surrounded by a liquid such as kerosene, was inclosed in a thick-walled steel bomb fitted with a movable leak-proof piston, and pairs of simultaneous readings were taken of (1) the displacement of the piston, *i.e.*, the volume-change, and (2) the pressure. The piston displacement was measured to within 0.01 mm. by means of a dial micrometer. In measuring the pressure, advantage was taken of the change of resistance under pressure of a "therlo" wire, and in order to determine the pressure to within 1 megabar the resistance change was measured with a type of Wheatstone bridge having no movable contacts. The P–ΔV graphs, which show the relation between volume-change and pressure, were found to be nearly straight lines; however, the more compressible metals exhibit a slight but unmistakable curvature, such that the graphs are concave toward the pressure axis. From this curvature a rough estimate was obtained of the change of compressibility between 0 and 10,000 megabars of all the solids examined (except gold, copper, silver, aluminum, and brass, for which the compressibiitiy is independent of pressure within the error of experiment).

(9) Some physical constants of mustard "gas." L. H. Adams and E. D. Williamson. J. Wash. Acad. Sci., 9, 30–35 (1919).

For military purposes it was desired to know the compressibility of the liquid 2, 2-dichloroethylsulphide, commonly known as mustard gas. With the apparatus already used for the determination of the compressibility of various rocks, metals, and other solids, it was a comparatively simple matter to make the requisite measurements. At the same time, certain other properties of this interesting substance were determined from its behavior under hydrostatic pressure. The compressibility (pressure being expressed in megabars) was found to be 49.6×10^{-6} and 23.9×10^{-6} at pressures of 1 and 2,000 megabars respectively, values which are about identical with those for water. From the measured change of volume upon melting and the slope of the curve of melting temperatures under various pressures, the latent heat of fusion was calculated and found to be 25 calories per gram.

(10) Note on the Bucher cyanide process for the fixation of nitrogen. Eugen Posnjak and H. E. Merwin. J. Wash. Acad. Sci., 9, 28–30 (1919).

In the course of an investigation of the Bucher cyanide process undertaken by the Laboratory at the request of the Nitrate Division of the Ordnance Department of the Army, it was found by means of microscopical examinations that the nitrogen-bearing constituent of some of the crude technical products manufactured by this process consisted principally of some other substance than ordinary sodium cyanide. Further experiments substantiated the microscopical evidence. The investigation of the chemical nature of the substance in question is being continued.

(11) An apparatus for growing crystals under controlled conditions. J. C. Hostetter. J. Wash. Acad. Sci., 9, 85–94 (1919).

Crystals, to be suitable for the study of the effects of pressure, must be perfectly developed and of comparatively large size. For the growth of such crystals apparatus is necessary in which *all* variables affecting rate of growth are controlled, and the device described here fulfills these conditions. Essentially, the apparatus consists of two thermostats connected in such a manner that solution may be continually pumped from one, containing feeding crystals held at a certain temperature, into the second, which is maintained at a lower temperature than the first and which contains the crystals to be grown. Crystals of potassium alum and sodium chlorate grown in this apparatus have been used for pressure studies, the results of which will be published later.

(12) An unusual sulfur crystal. F. Russell v. Bichowsky. J. Wash. Acad. Sci., 9, 126–131 (1919).

A description of an artificial crystal of sulphur showing unusual development of the prism zone, two new faces ζ (211) and β (310) and the rare faces λ (210); η (130); K (120), as well as the more common faces *c, b, a, e, m, v, s, y, p*, γ, *r, q*. A list of the known faces of sulphur is given, and certain new zonal relations pointed out.

(13) The technique of optical glass melting. Clarence N. Fenner. J. Am. Ceram. Soc., 2, 102–145 (1919). (Papers on Optical Glass, No. 7.)

This article is based upon the experience acquired in the manufacture of optical glass during the period of about 18 months in which the Laboratory was in cooperation with manufacturers of optical glass. The method pursued in the article is to follow the course of melting operations from beginning to end and describe the essential features of procedure. Details of practice which are common to all forms of glass-making and are familiar to glass-makers in general are either omitted or passed over with brief descriptions, and attention is concentrated on those matters in which the making of optical glass differs from that of other kinds. Because of the fact that the purposes for which optical glass is to be used are in many respects radically different from those of other glasses, and require that exact optical and other physical properties be maintained and that certain defects be eliminated, it is essential that manufacturing operations be controlled throughout by methods of precision. The article describes the general course which must be followed to accomplish these results and the effects caused by departures from the standard of procedure, and takes up in more detail the principal defects which are likely to occur, and considers their causes and the methods of avoiding them. Some of the subjects discussed are: the effects of different available batch-materials upon melting operations and the range of choice in this matter; the necessity of close temperature regulation and the results of inattention to this; fining operations, especially with reference to the elimination of bubbles, and the causes and prevention of bubbles in general; variations of optical properties from requirements, and to what they are due; differences of procedure required for the different types of glass; stirring operations, and the manner in which they should be conducted to obtain glasses relatively free from striæ.

(14) An improved method of optical glass manufacture. George W. Morey. J. Am. Ceram. Soc., 2, 146–150 (1919). (Papers on Optical Glass, No. 8.)

Stirring is begun during the fill and is continued during the fining period. Details are given of changes in procedure following this departure from the usual schedule. The results show that with proper furnace control the customary time of manufacture of a pot of glass can be reduced to 24 hours, with improvement in color due to diminished pot corrosion.

(15) Devitrification of glass. N. L. Bowen. J. Am. Ceram. Soc., 2, 261–278 (1919). (Papers on Optical Glass, No. 9.)

Devitrification of glass is the result of the tendency of the glass to reach the stable crystalline condition and takes place whenever the glass is held for a sufficiently long period of time within the range of temperature where its crystallizing power is great. The various forms of devitrification in glass are discussed from this point of view and suggestions are made as to the principle that must be borne in mind in deciding upon modifications of procedure or changes in composition that have as their object the avoidance of devitri-

fication. Specific examples of the devitrification of optical glasses are given, together with identification of the crystalline phases separating.

(16) The hydrated ferric oxides. Eugen Posnjak and H. E. Merwin. Am. J. Sci., 47, 311–348 (1919).

The work described in this publication proves rather conclusively that no series of hydrates of ferric oxide exists among the natural minerals. The only existing hydrate is ferric oxide monohydrate. This substance occurs in nature in two polymorphic forms—goethite and lepidocrocite—and in an "amorphous" condition—limonite. The two crystallized forms are contrasted as follows:

Goethite.—Orthorhombic, $a:b:c$ – 0.91:1:0.602; density (grams per c.c.) 4.28 ±0.01; $\alpha = 2.26$, $\beta = 2.394$, $\gamma = 2.400$; streak, dull orange-yellow; pleochroism faint. When crystallized in dense aggregates of thin blades and fibers inclosing much adsorbed and capillary water, it has commonly been called limonite; however, sufficient proof is now given to show that such crystallized material is really goethite.

Lepidocrocite.—Orthorhombic, $a:b:c = 0.43:1:0.64$; density (grams per c.c.) 4.09 ± 0.04; $\alpha = 1.94$, $\beta = 2.20$, $\gamma = 2.51$; streak, dull orange; pleochroism very strong.

The name limonite is retained for material which appears to be essentially isotropic ferric oxide monohydrate with adsorbed and capillary water. However, this substance should not be considered a distinct form of ferric oxide monohydrate, as the real nature of such "amorphous" substances is still uncertain.

The fibrous mineral turgite is variable in composition, and considerable evidence is given that it probably represents solid solutions of goethite with hematite, together with inclosed and adsorbed water.

The genetic conditions of the hydrated ferric oxides and the stability relation of the two monohydrates are unknown.

No definitely crystallized synthetic hydrated ferric oxide has up to the present been prepared. However, it seems certain that only two distinct types of "amorphous" hydrated ferric oxide exist, one yellow and the other reddish-brown. The yellow is apparently essentially ferric-oxide monohydrate, while the reddish-brown substance may hold its water in either a dissolved or an adsorbed condition (or both). Thus the synthetic and the natural hydrated ferric oxides exhibit, chemically, great similarity.

(17) Strains due to temperature gradients, with special reference to optical glass. E. D. Williamson. J. Wash. Acad. Sci., 9, 209–217 (1919). (Papers on Optical Glass, No. 10.)

General equations are derived for the elastic stresses produced by temperature differences in spheres, cylinders, and slabs when the temperature distribution is symmetrical about the center, axis, or central plane, respectively. More specific equations are given for the case of the temperature distribution due to uniform surface-heating, which is the most important case in practice.

(18) A furnace temperature regulator. Walter P. White and Leason H. Adams. Phys. Rev., 14, 44–48 (1919).

By making the heating coil of an electric furnace one arm of a wheatstone bridge, and combining this with a galvanometer regulator, thus keeping constant the resistance of the coil, we can, regardless of variations in the current-supply, and with no attention, maintain constant the temperature of furnaces not too directly influenced by the temperature of the room, or where the surrounding air is kept constant. The power available in this regulator

is relatively very great; nothing has to be inserted within the furnace cavity, and the lag is practically nothing; the regulator is often nearly at its best under conditions most unfavorable to other regulators. It has held a small furnace for hours constant to 0.1° at temperatures from 500° to 1400°.

(19) Temperature distribution in solids during heating or cooling. E. D. Williamson and L. H. Adams. Phys. Rev., 14, 99–114 (1919). (Papers on Optical Glass, No. 11.)

In deciding on the best methods of carrying out various operations in the manufacture of optical glass, we found it necessary to have some idea of the temperature gradients in the pieces during heat treatment. While great precision in absolute magnitudes is generally of minor importance in such cases, the only way to gain insight into the question of the variation of the temperature differences with the shape and dimensions of the blocks and the method of heating is actually to work out numerical cases.

Equations have been derived for the temperature distribution in solids of several typical shapes, the solids being heated or cooled according to one of two methods, viz, the surface of the body (1) is continuously heated (or cooled) at a uniform rate, or (2) experiences a sudden change to a higher or lower constant temperature. With these equations a number of calculations have been made and the results of the computations are presented in tabular form and, in certain cases, are also shown graphically. By the use of these tables and graphs it is a comparatively simple matter to determine the temperatures within solids of a large variety of shapes when, as is commonly the case, they are heated or cooled according to one of the methods mentioned above.

The equations given are in convenient form for calculation and for showing a number of interesting qualitative relations between the temperature gradients in various solids, and they will probably prove useful in connection with the determination of specific heat and thermal conductivity by dynamic methods.

While the main interest at the time was in the application to glass manufacture, the equations are perfectly general, as are also all the qualitative deductions made.

(20) The volatilization of iron from optical glass pots by chlorine at high temperatures. J. C. Hostetter, H. S. Roberts, and J. B. Ferguson. J. Am. Ceram. Soc., 2, 356–372 (1919). (Papers on Optical Glass, No. 12.)

Of all the ordinary impurities found in optical glass, iron exerts the greatest influence on transmission. The iron-content of the glass arises from pots used as containers during melting as well as from the raw materials. The content of iron in the glass and, therefore, its transmission, would be considerably improved if the iron could be removed from the pot-walls before use. Chlorine appeared to be a suitable agent for this purpose, and experiments demonstrated the fact that approximately 80 per cent of the iron could be extracted from the interior of the clay pots and volatilized by the action of chlorine at temperatures easily secured in a pot-arch or glass-melting furnace. Large-scale experiments were carried out at the Bausch and Lomb Optical Company and conditions developed for removing more iron from the bottom of the pot, where the most corrosion takes place, than from the side-walls. Glass melted in these pots showed, in all cases but one, less iron than that made in untreated pots. In the exception noted above, however, more iron was found in the glass made in the treated pot, and it was shown that, although the iron had been volatilized from the pot, more than usual pot corrosion had taken place during melting. The success of the method, then, depends on whether a dense surface can be made in such pots when the iron has been removed, as,

for instance, by burning under different conditions from that obtaining during the course of these experiments. With some types of pots the method would undoubtedly be successful, even with the usual burning schedules. The possible application to the removal of iron from grog, clay, and other ceramic products is indicated.

(21) Electrometric titrations, with special reference to the determination of ferrous and ferric iron. J. C. Hostetter and H. S. Roberts. J. Am. Chem. Soc., 41, 1337–1357 (1919).

The advantages of the electrometric method for titrating, oxidizing, and reducing reactions may be summarized as follows:

(1) This method permits the use of potassium dichromate with its numerous advantages.

(2) The reduction of the solution with electrometric control eliminates the removal of excess reducing agent, which must be done with the usual methods of reduction.

(3) Conditions, such as acidity, need not be controlled, except within very wide limits, and hydrochloric, sulphuric, or hydrofluoric acid, or mixtures of these, may all be used. In contrast to these wide limits, compare the narrow acid limits (1.5 to 2.5 per cent by volume of H_2SO_4) within which the reduction with SO_2 or H_2S must be carried out and the precautions which must be taken in a permanganate titration in the presence of either chlorides or fluorides.

(4) The sensitivity and accuracy of the method make possible (*a*) the determination of a few tenths of a milligram of tin, chromium, ferrous or ferric iron, and probably many other elements, in the presence of large quantities of some other element, and (*b*) the determination of blanks involved in some of the ordinary determinations by reducing or oxidizing agents.

(5) The time within which a determination can be carried out is greatly shortened. The content of ferrous and ferric iron in a silicate, for instance, can be determined in from 15 to 30 minutes.

(6) The precision attainable is comparable to the best of the ordinary volumetric determinations.

(22) Electrical apparatus for use in electrometric titration. Howard S. Roberts. J. Am. Chem. Soc., 41, 1358–1362 (1919).

A description of simplified and inexpensive apparatus for use in the titration of salts by the electrometric method. The potentiometer consists of a sliding rheostat with attached scale. Several forms of galvanometer may be used.

(23) The ternary system $CaO-MgO-SiO_2$. J. B. Ferguson and H. E. Merwin. Am. J. Sci., 48, 81–123 (1919).

The ternary system lime-magnesia-silica has proved to be the most complicated of the four possible ternary systems which may be constructed from the four oxides, lime, magnesia, alumina, and silica. The crystalline phases which are definite compounds, and which appear as primary phases, are as follows: Lime; magnesia; silica (tridymite and cristobalite); $\alpha\, CaO.SiO_2$ (pseudowollastonite); $3CaO.2SiO_2$; α and $\beta\, 2CaO.SiO_2$; $MgO.SiO_2$ (clino-enstatite); $2MgO.SiO_2$ (forsterite); $CaO.MgO.2SiO_2$ (diopside); $5CaO.2MgO.6SiO_2$; and $2CaO.MgO.2SiO_2$. The melting-point of $2CaO.MgO.2SiO_2$ is $1458° \pm 5°$ C. and the decomposition temperature of $5CaO.2MgO.6SiO_2$ is $1365° \pm 5°$ C.

In addition to these, crystals representing several solid solutions also appear as primary phases. The solid solutions are:

(1) A complete series with clino-enstatite and diopside as end-members, generally known as pyroxenes.

(2) The pseudowollastonite solid solutions whose compositions form an area bounded by the following lines: (1) the $CaO.SiO_2$ – $CaO.MgO.2SiO_2$ line; (2) a line running from the composition CaO 44.4, MgO 3.1, SiO_2 52.5 on the above-mentioned line across to the composition CaO 46.7, MgO 3.5, SiO_2 49.8, on the $CaO.SiO_2$ – $2CaO.MgO.2SiO_2$ line; (3) then either the last-mentioned line back to $CaO.SiO_2$, or, more probably, an approximate continuation of line (2), to about the composition CaO 50, MgO 50, on the side-line.

(3) The wollastonite solid solutions. These extend to about 17 per cent diopside or 3.2 per cent MgO at the higher temperatures. The most concentrated of these solid solutions along the diopside line (the 17 per cent) decomposes at 1340° ± 5°C., and this solid solution is the only one represented on the liquidus.

(4) The $5CaO.2MgO.6SiO_2$ solid solutions. Only a few of these solid solutions which are decomposed at the higher temperatures near the decomposition-temperature of the pure compound are stable in contact with a suitable liquid.

(5) Certain members of the monticellite solid solutions. Monticellite takes up forsterite in solid solution to the extent of about 10 per cent, and the decomposition-temperature of the solutions is thereby raised. Monticellite itself probably decomposes at too low a temperature to ever occur as a primary phase.

The temperature-concentration relations of the liquids which may be in equilibrium with each of these phases have been thoroughly investigated, where necessary, by means of the quenching method, and the results obtained have been correlated with the existing data on the remainder of the ternary system. The compounds $5CaO.2MgO.6SiO_2$ and $2CaO.MgO.2SiO_2$ have not been prepared previously. Attempts to prepare a compound of the formula $8CaO.4MgO.9SiO_2$ (Schaller's åkermanite) gave negative results. The monticellite solid solutions and the compound åkermanite are discussed at length, but the wollastonite and the $5CaO.2MgO.6SiO_2$ solid solutions are only briefly mentioned, as they are made the subject of a subsequent paper. (See abstract (24), below.) Experiments were made on the tridymite-cristobalite inversion temperature, which was found for this system to be below 1500° C., in approximate agreement with Fenner's original value of 1470°. The great sluggishness of the inversion precluded a more exact determination on our part.

(24) Wollastonite ($CaO.SiO_2$) and related solid solutions in the ternary system lime-magnesia-silica. J. B. Ferguson and H. E. Merwin. Am. J. Sci., 48, 165–189 (1919).

The study of the ternary system CaO–MgO–SiO_2 (described under No. 23 above) brought to light many perplexing liquidus relations for which there was no adequate explanation. An investigation of the solidus relations was therefore started in order to clear up the doubtful points, and the results of this investigation are given in this paper. The salient features of these results are:

(1) A confirmation of the earlier work in regard to wollastonite-diopside solid solutions, wollastonite taking up a maximum of 17 per cent of diopside.

(2) The existence of solid solutions of pseudowollastonite and diopside containing as a maximum about 16 per cent of diopside.

(3) The finding of the new compound, $5CaO.2MgO.6SiO_2$.

(4) The existence of solid solutions of åkermanite (or perhaps of an unstable compound, $3CaO.MgO.3SiO_2$) in wollastonite and pseudowollastonite. The wollastonite solutions extend to a composition containing between 60

and 70 per cent of åkermanite, while the pseudowollastonite solutions extend to a composition containing about 23 per cent of the same compound.

(5) The presence of an area of solid solution which includes the wollastonite-diopside, the wollastonite-åkermanite, and the wollastonite-$5CaO.2MgO.6SiO_2$ solid solutions. The decomposition temperatures on this area between the 17 per cent diopside solid solution and the compound $5CaO.2MgO.6SiO_2$ pass through a minimum. $5CaO.2MgO.6SiO_2$ decomposes at 1365° C. and the 17 per cent diopside solid solution at about 1340° C., while pure wollastonite inverts at 1200° C.

In addition to the results just mentioned, which suffice to clear up the liquidus relations in question, as thorough an investigation as the nature of the problem and the available methods of attack would permit was carried out upon the solid solutions of silica and $3CaO.2SiO_2$ in calcium metasilicate and upon the inversion and decomposition temperatures of all the various solid solutions.

A general discussion of these results, with diagram and models, is given. The formation of unstable phases in silicate melts is also discussed, and the futility of attempting to use formulas derived from the theory of dilute solutions in order to calculate the change of inversion temperature with solid solution is briefly mentioned.

(25) Use of optical pyrometers for control of optical-glass furnaces. Clarence N. Fenner. Bull. Am. Inst. Min. Met. Eng., 1001–1011 (1919). (Papers on Optical Glass, No. 13.)

Among the features of careful control required in the manufacture of optical glass, that of the regulation of furnace temperatures is of high importance. During most of the time that a pot of glass is in the furnace the temperature should be allowed to vary but little in either direction from that which has been found to be appropriate for the given stage of operation. It is therefore of great importance to have available a reliable means for the rapid determination of such temperatures. During the early experiences of the Laboratory in optical-glass making, it was perceived that the thermo-couples generally in use did not come up to the requirements of the case, and it was thought that optical pyrometers should be a satisfactory substitute. Before adopting them for general use, tests were made to determine to what degree the requirements were satisfied. Two principal questions were investigated: first, the correctness of the calibration table supplied with each instrument, and second, the degree to which radiation from furnace-walls agrees with that of a "black body," or a body whose intensity of luminosity corresponds to its temperature. The method of carrying out these tests is described in some detail, as similar tests are desirable wherever optical pyrometers are installed. As a result, it was found that the manufacturer's calibration tables were considerably in error in some cases (which implies that they should always be checked), and that the luminosity of furnace-walls agrees satisfactorily with that of a "black body" under some conditions but departs very widely under others. The reason for these results and the factors upon which they depend are discussed. The manner in which the pyrometer is used under working conditions is described. The conclusion is reached that when the readings of the pyrometer are properly checked by such tests as these the instrument gives a very satisfactory and reliable means of controlling furnace temperatures.

(26) The cooling of optical glass melts. Howard S. Roberts. J. Am. Ceram. Soc., 2, 543–563 (1919). (Papers on Optical Glass, No. 14.)

The conditions to be attained when a melt of optical glass is cooled in the pot are: (1) that neither ream nor bubbles shall be introduced during the

cooling, nor carried into the middle of the melt; (2) that the glass shall not become inhomogeneous through the precipitation of a crystalline phase; (3) that the bulk of the cooled melt shall be found cracked into large, reasonably rectangular blocks, having smooth, flat surfaces; and (4) that these blocks shall be sufficiently free from strain to cleave readily with a smooth fracture.

The appearance of ream in the middle of the melt, vacuum bubbles, or a crystalline phase, can be discouraged by rapid cooling, preferably from the bottom of the pot, while the glass is still soft; and by insulating its top surface as soon as the melt is set out of the melting-furnace.

The cold melt shows cracks of two types—"spherical cracks," and "plane cracks." The spherical cracks are due to decrease of temperature difference, and first appear below the temperature at which the drop is a maximum; these cracks form one after another until the temperature gradient has disappeared. The plane cracks seem to be the result of a difference in rate of contraction between the glass and the pot; the temperature at which they first appear in a given melt seems to be nearly independent of the cooling rate. The presence of either type of crack in the melt reduces the tendency for the other type of crack to form. As the fracture due to spherical cracks is rough and the pieces formed are irregular, while that due to plane cracks is entirely satisfactory, it is desirable to maintain the temperature gradient at a low value by slow cooling, and to prevent its decreasing much below its maximum until after the formation of plane cracks has begun. This can be accomplished by increasing the cooling rate at the proper time.

The cooling rate can be reduced (1) by heating the surroundings of the melt, *i.e.*, placing it in a heated kiln; and (2) by surrounding it with an envelope of some such insulating material as sand or kieselguhr. Variations of these two methods are described and time-temperature data given.

(27) Thermocouple installation in annealing kilns for optical glass. E. D. Williamson and H. S. Roberts. Bull. Am. Inst. Min. Met. Eng., 1445–1453 (1919). (Papers on Optical Glass, No. 15.)

During the war-time rush to prepare the glass necessary for the needs of the Army and Navy, the problem of the temperature control of the annealing kilns became most serious. This paper gives a short account of the system evolved by the members of the Laboratory staff who were cooperating with the Pittsburgh Plate Glass Company at its Charleroi plant. The points which are most specifically treated are:

(1) The advantages of the thermo-couple over other devices for this type of work.

(2) Choice of material for thermocouples.

(3) Choice of measuring instrument.

(4) Arrangement of leads and other apparatus.

(5) The general problem of annealing optical glass.

The conclusions reached will interest and assist those who have to meet similar problems in other fields.

(28) Potentiometers for thermoelement work. Walter P. White. Bull. Am. Inst. Min. Met. Eng., 1763–1772 (1919).

Thermo-couple pyrometers are read in three ways. First, by direct readers where the current, and therefore the deflection, is proportional to the electromotive force of the couple; second, by potentiometers where the galvanometer merely helps to balance the electromotive force of the couple against that of a standard cell by means of known resistances and a constant battery-current; third, by intermediate instruments such as the pyrovolter, employing

the potentiometer principle with a constant battery, but avoiding the standard cell, and measuring current with a calibrated galvanometer. Similar in result but different in principle is the new Harrison-Foote instrument, where the circuit resistance can be very quickly adjusted to the correct value. All these special instruments avoid the main difficulty of a direct reader, namely, the error from uncertain or variable resistance. It is necessary to use the regular potentiometer in order to avoid also the uncertainty (perhaps 1 per mille) of the calibration of the direct reader. With a slide-wire a simple and portable potentiometer is made, good to about 10 microvolts, or 0.25° with most thermo-couples. The slide-wire also permits readings to 1 microvolt, though not altogether satisfactorily. Two special designs of potentiometer, the Diesselhorst-Wolff and the White, enable readings to be made to 0.1 microvolt or better, and the White potentiometer is very little affected by corrosive gases. Both these are deflection potentiometers, enabling part of the readings to be taken direct from the galvanometer with a gain in speed and without sensible error. If the potentiometer is arranged as a double potentiometer, speed can be still further gained in reading different instruments simultaneously. The precision of these potentiometers exceeds that needed in ordinary pyrometry, but is useful in fundamental standardization work, in calorimetry, and in numerous other applications of the thermoelement.

(29) The rapid electrometric determination of iron in some optical glasses. J. B. Ferguson and J. C. Hostetter. J. Am. Ceram. Soc., 2, 608–621 (1919). (Papers on Optical Glass, No. 16.)

The results of the application of the electrometric determination of iron with stannous chloride and potassium dichromate are discussed in this paper. The electrometric method enables one to make rapid and accurate analyses for both ferric and ferrous iron, provided interfering substances are absent. Under favorable conditions, such an analysis can be made in 10 minutes and may be carried out in glassware. Four different procedures are described for total iron and one for ferrous iron. A number of analytical results, including many ferrous-iron determinations, are given. The ferrous-iron content of the glasses proved to be dependent upon a number of factors and in some cases reached values in excess of 35 per cent of the total iron present.

(30) Hematite and rutile formed by the action of chlorine at high temperatures. H. E. Merwin and J. C. Hostetter. American Mineralogist, 4, 126–127 (1919).

By the action of the vapors of a gas-fired furnace on the chlorides of iron and titanium at 1000° C., well-faceted crystals of hematite with a maximum diameter of 4 mm. were obtained. Excellent measurements were obtained which are identical with those generally accepted for natural crystals. Microscopic faceted rutile crystals also were obtained. Suggestions are offered for the growing of crystals of these substances.

(31) Application of the thermionic amplifier to conductivity measurements. R. E. Hall and L. H. Adams. J. Am. Chem. Soc., 41, 1515–1525 (1919).

As a part of the general plan for the investigation of two-component systems under pressure, a study is being made of the changes in solubility of a salt which occur when its aqueous solution, in contact with crystals of the solid, is subjected to pressure. In order to measure the changes of concentration which occur in the solution, while leaving it *in situ* in the pressure bomb, we note the changes in the conductance of the solution. For the attainment of sufficient accuracy in these measurements, the telephone which indicates the balance position of the wheatstone bridge must be extremely sensitive, since

the allowable current through the network is limited by heating effects in the conductivity cell. The terminals of the bridge which ordinarily are connected to the telephone are joined to the "input" of a thermionic amplifier of the type used in wireless telephony and telegraphy. The telephone is then connected into the output circuit of the amplifier. This arrangement has resulted in effectively increasing by approximately 50 times the sensitivity of a sensitive high-resistance telephone. Any ordinary telephone becomes a more sensitive instrument with the amplifier than the best telephones without it.

The electron tube employed in the amplifer may also be used as a source of alternating current for conductance measurements. Its advantages are its cheapness and the wide range of frequencies which may be obtained with it. A first harmonic is present in the current, which is noticeable at low frequencies but which is not troublesome at a frequency of 1,000 cycles or more.

If for any reason it should be desired to use frequencies in conductance measurements beyond the limit of the human ear, a telephone could still be employed to indicate the bridge balance by the use of the autodyne method.

(32) The hydrochloric-acid color method for determining iron. J. C. Hostetter. J. Am. Chem. Soc., 41, 1531–1543 (1919). (Papers on Optical Glass, No. 17.)

Conditions have been found under which the yellow color developed by dissolving ferric iron in hydrochloric acid may be used for the determination of iron. The temperature coefficient for this color varies from 2 to 3 per cent per degree, depending on the concentration of iron and probably also on the acidity. The color developed by a given amount of iron varies with the acid concentration, reaching the maximum intensity at from 26 to 28 per cent HCl. The relative increase produced by acid is greater the higher the concentration of iron; this is especially true above 20 per cent HCl, but below this concentration the relative change is independent of the iron content. Inasmuch as solutions must frequently be boiled in order to insure the complete solution of iron present as "scale," the use of constant-boiling acid is recommended and its use has been found to be altogether satisfactory. The effects of salts on the color indicate that sulphates cause bleaching and chlorides cause intensification; detailed study of the effect of the very soluble calcium chloride shows that an intensification of 2.5 may be attained by the addition of this salt; consequently, when testing for iron in a very soluble chloride the standard iron solution must be made up to possess the same salt concentration. Some applications of the method are given and some results are presented.

(33) Ammonium picrate and potassium trithionate: optical dispersion and anomalous crystal angles. Herbert E. Merwin. J. Wash. Acad. Sci., 9, 429–431 (1919).

The dispersion and other optical properties of the substances are given. The *b* axis of rapidly-grown trithionate crystals is longer than normal.

(34) Equilibrium studies upon the Bucher process. J. B. Ferguson and P. D. V. Manning. J. Ind. Eng. Chem., 11, 946–950 (1919).

The Bucher process is one of the processes by means of which atmospheric nitrogen may be "fixed" and thereby made available for the manufacture of explosives. An investigation of this process was undertaken at the suggestion of the War Department. Experiments were made using pure chemicals and mixtures of pure nitrogen and carbon monoxide in known proportions. Curves have been obtained showing (1) the relation between the carbon monoxide content of the furnace gases and the yield of cyanide, and (2) the

relation between the carbon-dioxide content of the furnace gases and the yield of cyanide, both at two temperatures. The curves indicate that under certain conditions producer-gas may be used in the process and that the dissociation of sodium carbonate is probably one of the controlling chemical reactions.

(35) The composition of the gases of Kilauea. E. S. Shepherd. Bull. Hawaiian Volcano Obs., 7, 94–97 (1919).

Since 1912, when Day and Shepherd collected the first gas samples ever taken from the Kilauea crater, work has continued on the composition of these gases. Further collection was made in 1917 and a shipment of gases collected by Dr. T. A. Jaggar, jr., director of the observatory at Kilauea, has just been received. This work presents rather unusual difficulties in the matter of collection and also in the analysis.

This preliminary report is concerned primarily with the 1917 collection, but includes a new analysis of one of the 1912 tubes and one tube from Jaggar's 1918–19 collection, for comparison. From an examination of the tables of analyses it appears that the gases from this volcano vary greatly in composition. About the only constituent which appears in more or less constant quantity is water vapor, which averages about 50 per cent of the gases given off by the lava. This refers, of course, to the gases obtained from the inside of flames, *i.e.*, before the gas has come in direct contact with air. The remaining constituents are CO_2, CO, H_2, N_2, Ar (trace), SO_2, Cl_2, and S_2, with traces of F_2. The chief ingredients are CO_2, SO_2, S_2, and H_2O. It seems significant that the combustible gases are (at the surface) relatively small in amount, and this doubtless explains the quiet nature of Kilauea eruptions—there is little left to furnish an explosion. It is also probable that with the additional evidence which the gases recently collected by Jaggar and the systematic collection which he purposes for the future will furnish, we shall be able to establish the relative importance of the several hypotheses thus far proposed to account for the energy supply of this crater. The analyses of the 1917 gases are as follows:

Gases collected from Kilauea, 1917.

[Volume per cents at 1200° C.]

Tube.	CO_2.	CO.	H_2.	N_2.	A.	SO_2.	S_2.	Cl_2.	H_2O.
1[1]	2.65	1.04	4.22	23.22	udt.	0.16	0.70	udt.	67.99
2[1]	17.95	0.36	1.35	37.84	udt.	3.51	0.49	udt.	38.48
3	33.48	1.42	1.56	12.88	0.45	29.83	1.79	0.17	17.97
4	11.12	3.92	1.42	......	0.51	......	8.61	0.02	77 50
5	9.54	1.12	1.53	10.47	......	9.90	2.72	......	64.71
6	1.97	0.82	0.21	3.50	0.07	0.95	2 70	......	89.77
7	17.25	0.62	0.76	5.88	0.18	9.75	1.07	0.25	64.18
8	15.27	0.45	0.70	0.87	0.14	6.98	0.49	......	75.08
9	8.32	0.82	1.82	8.92	0.29	16.80	2.49	1.01	59.97
10	1.54	0.43	0.37	2.44	0.39	......	3.56	1.34	89.93

[1] Tubes 1 and 2 were analyzed before the calcium tube was added to the apparatus, so that the rare gases were not determined. Chlorine was not determined in these tubes (udt.). Other blanks in the table mean that the gas was not present in determinable amounts.

(36) Tables and curves for use in measuring temperatures with thermocouples. Leason H. Adams. Bull. Am. Inst. Min. Met. Eng., 2111–2124 (1919).

Thermocouples are very convenient thermometers and play an important rôle in geophysical research. Previous publications from the Laboratory

have called attention to the advantages of standard calibration tables for translating the electromotive force of a thermocouple into temperature, and such standard tables have been given for copper-constantan and for platinum-platinrhodium couples. It has now been found advisable to extend the range of the copper-constantan table so that this couple may be available for measuring temperatures up to 400° and down to −200°. A table for chromel-alumel (the Hoskins couple) has also been worked out and the previous platinum-platinrhodium table for temperature between 0° and 1755° is reprinted without change. The question of fixed-junction corrections is discussed and the best methods for making such corrections are described in detail.

(37) The relations between tridymite and cristobalite. Clarence N. Fenner. J. Soc. Glass Technology, 3, Trans., 116–125 (1919).

Several articles have appeared recently in French and British journals, in which some of the conclusions regarding the stability relations between the various forms of silica, published several years ago (C. N. Fenner, The Stability Relations of the Silica Minerals, Am. J. Sci., 36, 331–384, 1913), have been questioned. The principal basis for doubt seems to the present writer to be not that new evidence has been discovered, but that the observers have failed to take fully into consideration the rather remarkable properties of silica, which tend to obscure stability relations and whose effect was discussed in some detail in the article cited; moreover, that some of the evidence set forth there has been overlooked or disregarded, and explanations have been advanced which are inconsistent with this evidence. For this reason it has seemed well to take up the matter anew and present the evidence which bears upon the specific points involved. The points at issue are especially those which deal with the relations between tridymite and cristobalite. Certain evidence previously given is repeated in somewhat different form, and to support it further evidence is offered which either has not been given before in detail or is entirely new. In addition to the writer's work, other directly relevant information supplied by the work of Ferguson and Merwin (see abstract 23 above) on the system CaO-MgO-SiO_2 is cited in confirmation. All of the results are in accord with the conclusions previously announced, and it is believed that the explanations suggested by the foreign observers are directly at variance with the experimental evidence. The conclusion is reached, as before, that the field of stability of tridymite is limited by the temperature of 1470° ± 10°, and that at higher temperatures up to the fusing-point cristobalite is the stable form.

(38) A method for determination of the volatile matter in oxides of lead. Olaf Andersen. J. Am. Ceram. Soc., 2, 782–783 (1919). (Papers on Optical Glass, No. 18.)

The amount of volatile constituents in a sample of litharge or other oxide of lead can be accurately determined by conversion of the PbO into $PbSiO_3$. The sample is mixed with a weighed quantity of silica, equal to about one-third the weight of the PbO; heated in a platinum crucible in an electric furnace at 800° to form lead silicate glass; quickly raised to 1000° for a few minutes; cooled and weighed.

(39) The volatilization of lead oxide from lead-silicate melts. Olaf Andersen. J. Am. Ceram. Soc., 784–789 (1919). (Papers on Optical Glass, No. 19.)

Experiments were made on the amount of PbO volatilized from the surface of lead silicate glasses at temperatures from 900° to 1400° C. It was found that the volatilization from an unstirred glass in 15 minutes took place at practically the same rate as from a stirred glass heated for a longer period.

The rate of volatilization falls off considerably during a long heating if the glass is not stirred, as a film considerably lower in PbO forms on the surface of the melt, into which PbO must diffuse from below before it can escape. The rate of volatilization of PbO at the temperatures usually employed in optical-glass manufacture would seem from these experiments to be small enough so that variations in refractive index due to volatilization are not to be expected if the procedure is reasonably constant from melt to melt, but large enough to cause considerable variations in index if the melting schedule is changed.

(40) War-time development of the optical industry. Fred E. Wright. J. Optical Soc. Amer., 2, 1–7 (1919). (Papers on Optical Glass, No. 20.)

In this paper a brief statement is given of the several factors which were involved in the high-speed production of fire-control instruments for the Army and Navy. The development of the manufacture of optical glass and the connection of the Geophysical Laboratory with this problem are described; the rapid increase in the manufacturing capacity of the country for precision optics to meet the urgent demands of the Army and Navy is outlined, and attention is directed to the results finally attained which insured an adequate supply of these instruments to June 1919.

(41) Sights and fire-control apparatus. Fred E. Wright. Chapter VI, pp. 135–147, of "America's Munitions, 1917–1918," Report of the Director of Munitions, War Department, Washington, 1919.

This chapter, which was written by Major Fred E. Wright in collaboration with Colonel H. K. Rutherford, presents a summarized record of the development of fire-control apparatus during the war, of the difficulties which were overcome in the production of optical glass, and of the conversion of other lines of industry to optical-instrument manufacture. A detailed statistical statement is given of the status of orders for fire-control apparatus on November 11, 1918 (the time of the signing of the armistice), and also on February 20, 1919.

(42) The oxidation of lava by steam. J. B. Ferguson. J. Wash. Acad. Sci., 9, 539–546 (1919).

Under certain conditions steam is capable of oxidizing iron and its lower oxides to magnetite, Fe_3O_4, or to ferric oxide, Fe_2O_3. This fact has often been quoted as an indication of the probable oxidizing action of steam upon the lava during an eruption. In this paper this reasoning from analogy is subjected to the light of recent investigations and found wanting. In addition, some experimental results are given which confirm the view that the ferrous iron is not thus oxidized, and which indicate that the presence of much ferrous iron in the lava and much steam in the volcanic emanations of Kilauea are two facts which are in full accord. Several miscellaneous experiments are also reported which show that in the experimental study of the chemistry of the lavas careful attention must be paid to the character of the gas phase in contact with the lava if results of value are to be obtained. The bearing of these experiments upon the interpretation of the results obtained by pumping gases from rocks at high temperatures need only be mentioned.

(43) George Ferdinand Becker, 1847–1919. Arthur L. Day, Am. J. Sci., 48, 242–245 (1919).

A review of the life and scientific work of Dr. George F. Becker, for thirty-eight years chief of the Division of Physical and Chemical Research of the U. S. Geological Survey and initiator of the researches out of which grew the present organization of the Geophysical Laboratory.

(44) The relation between birefringence and stress in various types of optical glass. L. H. Adams and E. D. Williamson. J. Wash. Acad. Sci., 9, 609–623 (1919). (Papers on Optical Glass, No. 21.)

In the examination of optical glass, the internal strains caused by poor annealing are detected by means of the birefringence which accompanies stress or strain. Since no adequate measurements of the quantitative relation between stress and birefringence were known, it was necessary to determine this relation in order to know the precise magnitude of the stresses commonly met with in unannealed glass. In this paper data are presented for nine different kinds of American-made optical glass.

(45) The nature of the forces between atoms in solids. Ralph W. G. Wyckoff. J. Wash. Acad. Sci., 9, 565–592 (1919).

The structure of the atom, as we now know it, is discussed with reference to the nature of the forces operating between atoms, and it is emphasized that the arrangement of only the outside electrons has a bearing on the phenomena usually included under the term "chemistry." The arrangement of the inner electrons can not be deduced from chemical data alone. The outstanding fact is the tendency, still unexplained, to form "closed clusters" of eight or twice-eight electrons.

Several typical compounds are considered with reference to the nature of the forces producing them. All compounds lie between the two extremes of "polar" and "non-polar" compounds. A simplified method of representing the type of combination in a given compound is suggested.

Solid substances are classified, according to the nature of the forces of combination, into molecule-forming, polar, and valency compounds.

The phenomena of adsorption, solubility, ionization in solution, formation of complex ions, and molecular complexes are discussed from this point of view.

DEPARTMENT OF HISTORICAL RESEARCH.*

J. Franklin Jameson, Director.

The following report, the fourteenth annual report rendered by the present Director, covers the period from November 1, 1918, to October 31, 1919.

Although the armistice was concluded early in the twelvemonth, many of the disturbing effects of warfare continued throughout the year. Taken as a whole, therefore, the year was far from normal, though by the end of it most of the Department's work had come back into the usual channels. The activities of the National Board for Historical Service, the war-time organization into whose action the war-work of the Department has been merged, have now come to an end. Leaving those activities to be described at a later time in a special report, the compiler of the present report confines it to those lines of work which lie in the normal field of such a department, in which it was engaged before the war, and from which, it is hoped, it will never again be called upon to depart.

The staff of the Department has suffered an important loss through the resignation of Miss Elizabeth Donnan, who has accepted an appointment as assistant professor of economics in Mount Holyoke College, and who in the middle of September left our service to enter the faculty of that institution. Her work in the Department, both in respect to the editing of the American Historical Review and in respect to the documentary historical publications of the Institution, had been of a very high order, and her departure could not fail to be regarded with deep regret. It is, however, believed that, by utilizing college vacations, it will be possible for her to finish the piece of work on which she was chiefly engaged in recent years, her two volumes of documentary materials on the slave-trade to America, illustrating especially the sources and methods of supply.

Miss Louisa F. Washington has taken the place of Mr. Campbell as the Department's stenographer.

In September 1918, Professor Dana C. Munro, of Princeton University, became chairman of the National Board for Historical Service, and Professor Joseph Schafer, of the University of Oregon, vice-chairman, with the understanding that the latter should be the active conductor of its work, resident for the time in Washington. In October 1918, Dr. Schafer came to Washington, under appointment as a Research Associate of the Carnegie Institution of Washington, and remained here until July. His presence was a source of great pleasure and profit to the Department, and he carried on a variety of useful work for the Board. The chief of these services was the untiring labor he

*Address: No. 1140 Woodward Building, Washington, D. C.

performed as chairman of a committee appointed by the Board and by the American Historical Association to draw up a comprehensive report upon the effects of the war on historical instruction in the schools of the United States, and to recommend such changes in the system as might adapt it better to the altered conditions which the war has brought upon the country in both external and internal relations. Dr. Schafer had for several months the helpful assistance of Miss Edith M. Stewart.

Another member of the Board, Dr. Victor S. Clark, formerly of the Department of Economics and Sociology in the Carnegie Institution of Washington, was constantly occupied from November to July with a special and highly important division of the Board's work, and thus was closely associated with the staff of this Department.

As in previous years, acknowledgment is cordially made of the favors constantly shown to the Department, with the greatest liberality, by the officials of the Library of Congress, and especially by Dr. Herbert Putnam, the Librarian, by Mr. A. P. C. Griffin, acting librarian, by Mr. Charles Moore, acting chief of the Manuscripts Division, and by Mr. P. Lee Phillips, chief of the Map Division. Grateful recognition is also made of special courtesies extended by the authorities of the libraries of Harvard University and of Bowdoin College, especially during the summer months, to several members of the staff, of the great kindness shown by the South Carolina Historical Society and its librarian, Miss Mabel L. Webber, to Miss Donnan, and of that shown by the New York Public Library and the Public Archives of Canada in facilitating the work of Mrs. Surrey.

WORK OF THE PAST YEAR.

REPORTS, AIDS, AND GUIDES.

As has been indicated by preceding reports, a large part of the work of the Department has consisted in the gradual preparation and issue of a series of guides to the materials for American history preserved in the archives of foreign countries. The series was approaching completion when the war broke out. In times of warfare its continuance was surrounded by so many difficulties that attempts to go on with it were deemed inexpedient. Many of the same obstacles still exist, but it was thought possible in April to undertake archival investigations in the neutral territory of the Netherlands. Mr. A. J. F. van Laer, archivist of the State of New York, and the person whom the general judgment of scholars would pronounce the best qualified for the purpose, was able to secure three or four months' leave of absence from his post at Albany, through the kindness of the regents of the University of the State of New York. He was accordingly invited to undertake for the Department the preparation of a guide

to the materials for United States history in Dutch archives, and in April proceeded to the Netherlands for that purpose. Although the Dutch archives are voluminous, and, by reason of the federal character of the old Republic, less centralized than those of most European countries, and although three months was therefore a short time for the preparation of even a preliminary survey such as our system contemplates, yet certain considerations made the available time seem not inadequate.

The Dutch archives are exceedingly well arranged. Their officials are exceptionally helpful. Mr. van Laer, a Dutchman by birth, was already familiar with the archives, and with the portions of American history (New Netherland, etc.) to which they chiefly relate. Moreover, much time would be saved by reason of the fact that, 75 years before, John Romeyn Brodhead, as historical agent of the State of New York, had made a careful search of Dutch archives, and in his report printed in 1845 had presented itemized lists of the documents relating to New Netherland then found in those repositories.

During Mr. van Laer's three months in the Netherlands he received every desirable courtesy from the officials of national, provincial, and municipal archives, of the archives of the House of Orange, and of those of various religious bodies. He returned late in August, with a rich store of notes additional to those of Brodhead, and is now preparing his report.

Students of American colonial history are agreed that its study ought to include a much fuller consideration of the history of the British West Indies than has hitherto been customary. On the one hand, the commercial relations between the island colonies and those of the mainland form an important part of the economic history of the latter. On the other hand, the history of the British Empire in America and of its administration can not be rightly understood except by taking into the student's view not the continental colonies alone, but the whole series of dependencies, continental and insular alike. At times the island colonies were a more important element in the Empire than those of the continent. To study the "Old Thirteen" alone is a false method. It is to import into the history of our colonial period a distinction which did not then exist, and in so far to distort and mutilate that history.

Accordingly, it had been resolved that the archival materials for the history of the British West Indies deserved early treatment at the hands of this Department, and the more so as it was not to be expected that these now small communities should each be able to put into print the original materials for its early history (which some of our richest States have done to but a small extent), or that they should do it in so uniform a manner as to serve the needs of those who wished to study, not a single island, but the Empire as a whole.

Inevitably, however, this task falls into two parts: to deal with the archives in the islands, and to deal with the papers relating to the islands in the imperial Public Record Office in London; for the archives in the islands have suffered such losses by reason of hurricanes, earthquakes, volcanic eruptions, peculiarities of climate, the ravages of insects, and occasionally by warfare, that some of the most important series are found more complete in the Public Record Office than in the islands, the colonial governors having been required by their instructions to transmit copies of these series to the home government. The transcripts which went to London are in almost all cases still there, while the originals which remained in the islands have often perished. Thus the two collections are mutually complementary. Many of the series in the islands are to be found nowhere else, copies of them not having been transmitted to London; there are, as in the case of the continental colonies, many sorts of colonial documents in London that are not to be found in the islands; and some of the most important series are to be found both in the islands and in London, but as a rule much more complete in the latter case.

Under such circumstances we have, as has been intimated above, two tasks to perform: the exploitation of the archives of the British West Indies, and that of the various series relating to them in the Colonial Office papers in the Public Record Office in London. A beginning of the former task was made in September and October 1916, when Mr. Luis Marino Pérez, librarian of the Cuban House of Representatives, prepared for the Department a full and careful report upon the archives of the island of Jamaica. But the war, submarine activities, and the scattered state of the Lesser British Antilles made it inexpedient to continue. In June of the present year, however, it became possible for Professor Herbert C. Bell, of Bowdoin College, who had long ago been engaged for the work and was now released from military service, to attack the London portion of the problem. Proceeding to London, and permitted by the kindness of the president of Bowdoin College to prolong his absence a little beyond the autumnal opening of the college, he has been able to collect most of the essential materials for a summary inventory of the West Indian portion of the Colonial Office papers to the year 1775. Of the chief series, those called "Original Correspondence" and "Entry-books," he has himself prepared the inventories. For some other series, having more of a routine character, clerical aid was invoked and was adequate. For the series of "Sessional Papers," chiefly journals of councils and legislative assemblies, Messrs. B. F. Stevens and Brown supplied the skillful aid of Miss Edith Moodie, who some years ago prepared for the American Historical Association its excellent catalogue of journals in London of the thirteen colonies which subsequently formed the United States. This part of the work is not yet completed, but will no doubt be finished

in season for incorporation in the proposed "Guide." It is not intended that the Department's West Indian volume shall be sent to press until the other and complementary portion of the work has been completed, the inspection of the island archives. With Dr. Bell's report upon the latter, including those of Bermuda, will be incorporated Mr. Pérez's material on those of Jamaica, and a special report on the archives of the Bahamas, already in the possession of the Department.

It is possible that the same volume may also be found to be the most convenient place in which to describe the small amount of American material to be found in the archives of Scotland and Ireland. Miss Sybil Norman, of Edinburgh, who in previous years has worked under Mr. Leland's direction in the archives of Paris, has made considerable progress in a systematic search of those of Edinburgh for papers bearing on American history. Much material for the history of the Darien Expedition has been found, but no great amount of other American matter.

Mr. Leland's duties as secretary of the National Board for Historical Service and as secretary of the American Historical Association have, during this year also, prevented him from devoting much time to the "Guide to Materials for American History in Paris Archives," on which he has been so long engaged. The ending of warfare has, however, released from the French military service Mr. Abel Doysié, who before the war had so admirably assisted him. Resuming work in April, Mr. Doysié has dealt with the new manuscript accessions (since 1914) of the Bibliothèque Nationale, with the manuscripts of the library of the Senate, the Arsenal, and the two great libraries of the Marine. He has made a beginning in the library of the Institute. His work has been planned in accordance with the project of publishing first that one of the three volumes of the "Guide" which has to do with manuscripts in Parisian libraries.

Mrs. Surrey has continued her work of editing for publication a calendar of papers in Paris archives and libraries bearing on the history of the Mississippi Valley, based on notes taken in Paris under Mr. Leland's direction. Working with great assiduity, she has now completed a total of 17,500 cards. Through November, December, and January her field of work lay among the transcripts lately obtained from French archives by the Library of Congress, which enabled her to verify or amend the data taken from the originals in Paris. Later, in May and June, several weeks' work among the Paris transcripts in the Public Archives of Canada, at Ottawa, enabled her to carry out the same process through still another section of the material laid before her. The rest of her work upon it has been done in the New York Public Library.

In the work upon the "Atlas of the Historical Geography of the United States," Dr. Paullin, with the aid of the draftsman, Mr. J. B.

Bronson, has completed the series of maps showing, at different periods, the negro and slave population of the United States. He has also prepared the letterpress accompanying this series. He has completed a series of nine maps showing foreign-born population since 1860, has brought well toward completion a series of eight illustrating immigration since 1820, and has done parts of the work necessary for the maps illustrating colonial charters and patents, territorial claims of European powers, cessions of land by Indian tribes, and the history of the public domain of the United States.

Mr. David M. Matteson, of Cambridge, has devoted a large part of his time during the year to the compilation described on pages 142 and 143 of the last Annual Report of the Department. The work has proved to be of much greater magnitude than was expected, but conviction of its utility remains undiminished. It consists of two parts. It is necessary, first, to find, by thorough bibliographical search in various libraries, all the catalogues they contain of the collections of manuscripts in European libraries, including those lists embedded in general catalogues, and all those small or fragmentary catalogues of manuscripts that are to be found in, or heard of through, learned periodicals or similar repertories. The second process is that of searching these catalogues for those items that disclose and describe manuscripts relating to American history, and drawing off those items for use in the proposed manual. The first of these two processes is now nearly complete, so far as the libraries of Boston, Cambridge, and Washington are concerned (Mr. Matteson having spent June in Washington), and not much is likely to be found by such searches in other American libraries as are contemplated. The second process has been carried out in the case of those catalogues found in the Library of Congress and not found in the libraries of Boston and Cambridge.

TEXTUAL PUBLICATIONS OF DOCUMENTS.

Miss Davenport has been able to make ready for publication four more treaties, 1662–1667, for the second volume of her "European Treaties bearing on the History of the United States."

Dr. Burnett has advanced the final preparation of his "Letters of Delegates to the Continental Congress" to the beginning of May 1781, completing somewhat more than the third volume of the manuscript. When the Director had finished his examination of the manuscript of the first volume, it was concluded to effect, in the interest of economy in press corrections, and of consequent exactness in printing, a change in the whole system of cross-references in footnotes. This has delayed presentation of the manuscript, but it is now ready, and volumes II and III will be ready, and will be offered for publication, as soon as the Director has found time to carry through his own examination of these manuscripts. The first volume runs from the beginning of

Congress in September 1774 to July 4, 1776; the second volume to the end of 1777; the third to June 30, 1779.

Until February, Mr. Stock was able to do little else than to perform the duties which fell to him as assistant secretary of the National Board for Historical Service, and even since that date those duties have consumed in each month a part of his time; but in the last nine months of the year reported upon he has been able to devote himself mainly to his regular work of editing the "Proceedings and Debates of Parliament respecting North America." The work of gathering together the materials having been substantially completed long ago, his present work is mainly that of annotating the texts. This has now been carried into the period of the Long Parliament and to the end of 1640. Miss Galbraith has finished the decipherment and transcription, from photographs procured from the British Museum, of the American passages in Henry Cavendish's shorthand notes of debates in the "Unreported Parliament" of 1768–1774.

Miss Donnan returned in February from her temporary service as a substitute teacher in Mount Holyoke College, and from that time until her permanent transfer to that institution in September was occupied with her collection of documents and narratives illustrating the history of the African slave-trade and of the importation of slaves into English America. For some two months she was in South Carolina, occupied chiefly in the examination of the papers of Henry Laurens, a collection rich in materials for the history of slave importations into South Carolina, to which she was given the fullest access by the South Carolina Historical Society, the present owners of the collection. Other researches in Charleston, in Columbia, and in Richmond were also carried out. It is believed that the search for unprinted material in the United States has been nearly completed. Much of that material has already been copied. There will be no hesitation in including also considerable amounts of material from books already printed, since many narratives and descriptions having much importance to the subject are contained in old books of the eighteenth century, found in few American libraries or written in languages with which few American historical students are familiar. Most of the book has, however, been taken from manuscript sources, and this proportion will be much increased by the searches yet to be made in London archives and in the British Museum. That part of the material which has been taken from American colonial newspapers, such as the unique file of the *South Carolina Gazette*, is, on account of the rarity of these papers, regarded in the same light as manuscript. The collection, viewed in its present state of advancement, bids fair to be one of great interest and historical value.

Mrs. Catterall has been able to devote a part of her time to the compilation described on page 144 of the last annual report, the ex-

traction of the material for the history of slavery which is to be found in the judicial reports of the American States. Her work has consisted partly in summarizing briefly the judicial decisions through which we can trace the historical development of the law respecting slavery, and partly in extracting from the reports those numerous narrations and original documents which illustrate by a multitude of actual instances the whole history of slavery as a social and economic institution. A year ago Mrs. Catterall had finished the Maryland reports. She has now finished those of South Carolina, and begun those of Kentucky. From the beginning of October 1919, she is able to devote to our service all of her working time.

MISCELLANEOUS OPERATIONS.

As heretofore, the editing of the *American Historical Review* has been carried on in the office of the Department and by its staff. The American Historical Association and various other historical organizations have been given such aid as could appropriately be rendered, in respect to investigations in Washington and other services, and many queries from individuals have been answered. The rendering of such services in Washington to scholars at a distance is the more necessary and the more useful, because of the continued neglect of Congress to provide in Washington a suitable National archive building, without which it is impossible that the rich materials for history contained in the Nation's capital should be much other than a trackless wilderness, from which students remote from Washington can not hope to derive much benefit except through the mediation of such an organization as the staff of this Department, necessarily more familiar with the ground.

The Department has also gladly made itself useful to historical inquirers in procuring transcripts from foreign archives, especially, this last year, in the cases of Seville and Rome.

In the matter of the transcripts made in Seville for the Carnegie Institution by the late Dr. Adolph F. Bandelier, much progress has been made by Dr. Hackett and his assistants, though the task is not yet completed. A year ago all the work of copying for the printer had been finished. The amount of text, after deduction of some matter which had already been printed, was about 405,000 words. It happened that certain documents in the Peabody Museum at Cambridge, certain others in the Ayer Collection in the Newberry Library at Chicago, and a group from the Bancroft Library in the possession of the University of California would helpfully supply gaps in the various series of documents transcribed by Dr. and Mrs. Bandelier. The addition of a moderate number of these was accordingly authorized. The respective custodians of these collections kindly permitted the desired papers to be transcribed. The total amount of text has thus been raised to about 460,000 words, enough to make two volumes of the

Institution's publications, to which the translations would add two more. All but about 50,000 words of this material had been translated into English by the end of September. The work of translating will soon be completed. That of editing the documents and writing the introductions for the several groups into which they have been divided has been held back by two removals on Dr. Hackett's part, two attacks of illness, and the imposition of new duties at the University of Texas from which he could not escape. It will, however, not be very long before the first half of this work will be finished, an amount sufficient to constitute two volumes of print.

PLANS FOR 1920.

The work of the National Board for Historical Service is ended, and the Department will no longer feel obliged to devote strength and time and money to work called for by the immediate exigencies of warfare, but its remoter consequences will permanently continue to affect our work. All historical work hereafter carried on will feel the impress of the great war and the resulting social upheaval, just as the historical work of the three generations preceding has felt the impress of the French Revolution and the Napoleonic conflicts. Just what readjustments or new lines of work this should suggest in the case of an organization occupied solely with the raw materials of history, with searching for the original documents, making them accessible to scholars, and printing some of them, is a question so grave and one requiring so deliberate consideration that the next year may well be devoted to thought and planning on this subject, to collecting information and formulating proposals, without attempting now to make detailed or definite suggestions as to what should be undertaken under the new conditions of the historical and the general world. In brief, it must be our desire that the Department shall do whatever will be most useful to the advancement of historical science in America, that it shall so take cognizance of the work of other historical agencies as to avoid doing what has been or is likely to be abundantly well taken care of by others, and that it shall do its part in any projects of international cooperation which will not have the nature of "entangling alliances." Always the endeavor will be made to keep in mind the great responsibilities which are placed on American scholarship by the results of a war which has signally impaired the sources by which scholarly enterprises in Europe have been sustained, while it has left American resources, relatively speaking, almost untouched.

REPORTS, AIDS, AND GUIDES.

It is hoped that Mr. van Laer's report on the materials for American history in Dutch archives, based on his recent expedition, will be presented during the earlier part of the year, and that of Mr. Bell on the West Indian papers in the Public Record Office.

Mr. Leland will do what he can toward finishing that volume of his Guide to Materials in Paris which concerns manuscripts in libraries. Mrs. Surrey may reasonably expect to finish her calendar of papers in Paris archives relating to the history of the Mississippi Valley. Mr. Matteson, part of whose time is always taken by other work than ours, will do what he can toward finishing his inventory of American material compiled from the printed catalogues of manuscripts in European libraries. Dr. Paullin will continue his work upon the "Atlas of the Historical Geography of the United States."

TEXTS.

Miss Davenport will progress with her second volume of treaties; Dr. Burnett with the later volumes of his "Letters of Members of the Continental Congress," of which the Director expects to present the second and third volumes for print during the year. Mr. Stock will be given, as nearly as possible, unobstructed opportunity to proceed with the editing of his Parliamentary materials.

It is hoped that Miss Donnan may be enabled to spend the summer, during the vacation of Mount Holyoke College, in further work upon her collection of materials on the slave-trade.

MISCELLANEOUS OPERATIONS.

The Department will no doubt maintain, in 1920, activities similar to those which, under this heading, have been described above in that part of this report which relates to the year now closed.

DEPARTMENT OF MARINE BIOLOGY.*

ALFRED G. MAYOR, DIRECTOR.

In December 1918 the students of the United States Officers' Naval Training Unit at Princeton University were discharged, thus relieving the Director from his duties as instructor in navigation to the school for ensigns in the Naval Reserve.

Also, on January 2, 1919, the Navy Department returned the yacht *Anton Dohrn*, which had served as a patrol vessel guarding Key West harbor, being designated as S. P. No. 1866 in naval records. She had been leased to the United States Navy since July 31, 1917, for $1 per annum.

Accompanied by Dr. Paul Bartsch, the Director went with the *Anton Dohrn* to inspect the Tortugas Laboratory, which we had been unable to visit since August 1917. Our chief object was to ascertain the condition of the property and to form an estimate upon the cost of repairs and expenses of upkeep. We also wished to provide Dr. Bartsch with an opportunity to study the colonies of Bahama cerions which he had established on the Florida Keys between the mouth of Key Biscayne Bay and Tortugas in 1912, and which had given rise to a generation derived from parents born in Florida.

Dr. Bartsch found that on New Found Harbor Key the Bahama cerions belonging to the *Glans* division of the genus had crossed with the native Florida cerions, which belong to the *Incanum* division. The first generation of hybrids show characters about intermediate between the two parent stocks, but the next generation born of these hybrids exhibit an extraordinary variety in form and color-pattern, giving rise to many individuals quite unlike any cerions hitherto known, and so distinct that they may prove, should they breed true, to be new species derived from a new equilibrium of chromosome elements due to recombinations resulting from the cross. The matter may throw light upon the manner of origin of the numerous localized races of *Achitenella* in Oahu or of *Partula* in the valleys of Tahiti.

In order to test its biological significance, Dr. Bartsch again visited Tortugas in May, and 105 wire cages were made by Mr. John Mills and placed out upon the meadow in the center of the island in order to enable him to isolate selected pairs of these snails in an attempt to study the inheritance of characters in their offspring. These cages were, however, destroyed by the hurricane of September 10, 1919, and it will be necessary to start the experiment again as soon as possible.

Also, at Tortugas we took up the corals which had been planted out upon the reefs in July 1917, and these showed that when, on account of old age, a coral has ceased to grow or is growing slowly, isolating

*Situated at Tortugas, Florida.

small pieces of this coral does not revive the growth-rate, such separated pieces growing at the characteristic rate of the major stock from which they were removed.

While some species of Florida corals, such as *Orbicella annularis*, may continue to grow for at least 300 years, most of the reef species, such as *Acropora*, attain full size in 10 years or less, and then cease to grow, but still survive for an undetermined period until overcome by the attacks of seaweed, bryozoa, millepora, boring algæ, other organisms, or silt, the encroachments of which, due to physiological senescence, the coral has become unable to resist. These factors are the common causes of death of coral-heads on the reefs.

The impossibility of forming any definite plan for the year's work until the termination of hostilities, and especially the unprecedentedly high cost of essential materials and of labor, and the continued absence of many of our leading investigators in war work, have made it difficult to carry out our normal program of research.

The long-delayed and very expensive repairs to the yacht, launches, and laboratory buildings have also consumed so much of our annual appropriation that we have been obliged to curtail much research we had hoped to carry out during the year. Prices of apparatus and of most essentials were quite double those prevailing in 1917 and delivery of all manufactured articles was delayed to such a degree that in some cases our research work suffered seriously.

The following investigators studied during the year under the auspices of the department:

Dr. Paul Bartsch, January 1 to 23, May 1 to 17. Heredity of characters in Bahama-Florida cerions.

Dr. Joseph A. Cushman, May 14 to June 3, at Tortugas. Foraminifera.

Professor R. A. Daly, May 14 to June 3, at Tortugas; July 21 to September 16 in Samoa. Geology of Tutuila and other islands of Samoa.

Professor Ulric Dahlgren. Development of electric muscles in the electric eel, *Gymnotus*.

Dr. Richard M. Field, June 5 to 19, Tortugas. Limestones of Florida reefs.

Professor W. H. Longley, June 5 to July 1, Tortugas. Submarine stúdy of ecology of reef fishes.

Professor J. F. McClendon, June 5 to 19, Tortugas. Anesthesia in marine animals.

Alfred G. Mayor, Tortugas, and Tutuila, Samoa. Effect of diminution of oxygen on rate of nerve conduction. Rate of nerve conduction in regenerating tissue lacking muscles. Growth-rate of Samoan corals at various depths down to 8.5 fathoms. Effects of currents in transporting sediment over reefs. Losses in reef material due to boring algæ, solution, holothurians, etc. Detection of ocean currents by observing their hydrogen-ion concentration.

Professor Asa A. Schaeffer, May 17 to June 19. Marine amœbas from Tortugas.

R. C. Wells, June 7 to 19. Carbon-dioxid content of Tortugas sea-water.

A fund was deposited with Dr. C. William Beebe to obtain information respecting the breeding-season of *Gymnotus*, the electric eel of Guiana, in order to enable Professor Ulric Dahlgren to make plans for the study of its embryology and the development of its electric organs.

Professor E. Newton Harvey returned from Japan in January 1918, whither he had gone upon a successful expedition to gather material for further experiments upon the chemistry of light-production in marine animals, and he gives herewith a second report upon this study. Details of work accomplished by the investigators at Tortugas appear in their special reports; but a brief summary of the scope of these researches may be of interest.

Dr. Paul Bartsch attempted to install his extensive breeding experiments upon cerions not only at Loggerhead Key, Tortugas, but in a specially constructed vivarium in his home in Washington, wherein the temperature, degree of humidity, and other environmental factors are made to imitate those of the Bahama-Florida region. He hopes thus to acquire an insight into the life-history and breeding habits of these snails and to supplement the breeding experiments to be reinstated in Florida, the original attempt upon the Tortugas having failed, due to the hurricane of September 10, 1919.

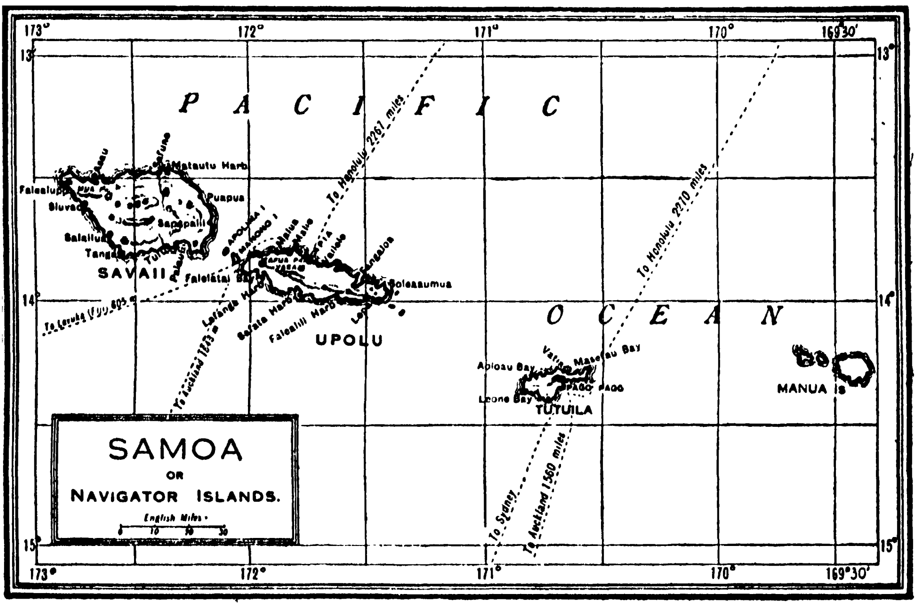
At the Tortugas laboratory, in May, Dr. Joseph A. Cushman studied the foraminifera of the region. Studies were made of the rate of movement of the living animal in *Iridia diaphana* and other species, the structure of the tests, and the cell contents.

Collections were made of the bottom foraminifera in various depths inside the lagoon and in the water immediately outside the reefs. These will furnish material for a report on the foraminifera of the shallow water of the region. Very little is known at present of the foraminiferal fauna of the shallow water of the West Indian and Florida regions. A comparison will be made of these recent collections with those of the Coastal Plain Tertiary, in order to determine something of the ecological conditions under which these deposits were made.

Professor Reginald A. Daly discovered that beach-rock, or coquina, occurs only on shores subjected to heavy breakers. A promising hypothesis to account for its formation, as indicated in his special report, is that when sand is torn up from the bottom by storm-waves and cast ashore it is necessarily charged with much organic matter, the decomposition of which generates alkalies which through chemical action cause the interstitial deposition of calcium carbonate, thus binding the grains of sand together and forming a rock-mass.

From July 21 to September 16 Professor Daly studied the bed-rock geology of Tutuila, Samoa, and made an extensive collection of the volcanic rocks of this island. Due also to the kindly interest of his Excellency Commander Warren Jay Terhune, U. S. N., Governor of Samoa, he was enabled to visit the islands of Anuu, Tau, Ofoo, and Oolosega, in the U. S. S. *Fortune*, and later he spent a few days upon Upolu. He will report in detail upon the lithology of these islands, but a preliminary account of some of the more apparent conclusions are presented in his account published herewith. It may be noted that he

confirms the Director's observations that there are no limestones of any sort upon the elevated shore-bench, which is found all around Tutuila, except off the recent lava-flow between Tafuna and Sail Rock. This shows that at one period the island was not surrounded by coral reefs and is in conformity with the conclusion that the present living reefs of Tutuila are not superimposed upon any ancient reefs, but have simply grown outward upon the wave-washed shore-slopes and spur ends since post-glacial times, the remarkably rapid growth-rate of Pacific corals necessitating this conclusion.



Alfred G. Mayor extended his observations upon growth-rate of Samoan corals by planting weighed, measured, and photographed corals at depths ranging from shallow water to 8.5 fathoms. Experiments upon the growth-rate of *Lithothamnion* and upon the loss in weight of dead and corroding coral-heads were also instituted. Using a diving-hood, he made a somewhat detailed study of the submarine seaward wall of the reef of Tutuila. In regions subjected to heavy breakers the *Acropora* and *Pocillopora* constitute 97 per cent of the coral-heads at depths of 1 to 4 fathoms, and these genera have the most rapid growth-rate of all Pacific corals. In silted regions the submerged outer wall of the reef is composed chiefly of branched *Porites*, a genus which is extremely rare on the submarine slopes fronting the open ocean. In quiet regions of pure water free from silt a great variety of corals constitute the fauna of the submerged walls of the reef.

Below 4 or 5 fathoms the coral-heads are generally smaller and not so numerous as they are at lesser depths, and at 8.5 fathoms fronting the

open ocean the slope is covered with small, apparently stunted heads of *Acropora*, most of which are about 6 inches and very few more than a foot in diameter. Reef corals practically cease at 18.5 fathoms.

Studies were made of the currents over reef-flats, using an Ekman meter. It was found that a great variety of corals may thrive in pure water at depths of 1 to 8 fathoms where there appears to be no measurable current; but silt is soon fatal to them in such regions.

The limestone sands of Samoan reef-flats begin to be transported when the current moves at the rate of 42 feet per minute; and a current of 59 feet, observed during a gale, caused a decided disturbance and movement of sand all over the bottom of the Aua reef-flat.

Our heavy expenses at Tortugas, and in repairs upon the *Anton Dohrn*, made it necessary to curtail the program of boring through the reef to enable Professor L. R. Cary to study its structure. On this account, Professor Cary did not come to Tutuila this year, but expects to resume his studies in the Pacific in 1920. One boring with the Davis-Calyx drill was, however, made by Mr. Mills off Utelei 200 feet from shore, and hard, wave-worn basaltic rock was found to be underlying the reef at a depth of 68 feet. The upper part of the reef was composed chiefly of loose fragments of *Porites*, *Acropora*, and *Alcyonaria*. Limestone sand was encountered at a depth of 33 feet and continued to the bottom of the boring. Professor Cary will study the material taken from the boring.

The alcyonaria planted out by Cary in 1918 had made a vigorous growth, and these observations, combined with those upon the growth-rate of stony corals and alcyonaria in Samoa and Fiji, will furnish a basis for an estimate of the age of the living reefs of the Pacific. The rapidity of coral growth is such that these reefs appear to have developed since the last glacial period, and the nearly uniform width of atoll rims over the Pacific suggests that they are all of about the same age.

Professor William H. Longley continued his observations upon reef fishes at Tortugas, obtaining an excellent series of submarine photographs illustrating the relations between the color patterns of these animals and the general color-scheme of their surroundings. These studies have been pursued for 8 years in the Florida-West Indian region and in the Hawaiian Islands, and it is hoped they may be supplemented in 1920 by further work in the Pacific, in order to give them a world-wide significance.

Professor J. F. McClendon found that the neuro-muscular system of the scyphomedusa *Cassiopea* has the same rate of metabolism when etherized as it has when in normal sea-water. He also found that an excess of carbon dioxid in sea-water lowers metabolism in *Cassiopea*, and this depression is not due to hydrogen-ions in the surrounding water derived from hydrolysis of CO_2, but to carbon dioxid *per se*.

In this connection Mayor determined the death temperature of Tortugas corals in normal sea-water, and also in water heated to the same temperature but made acid by adding HCl so as to be about 6 PH, or in other experiments by adding CO_2 so as to produce the same degree of acidity. The corals died at the same temperature in this acid sea-water as in normal sea-water, but the lowering of metabolism due to CO_2 tends to counteract the effect of heat to raise metabolism and the animals produce less CO_2 when CO_2 is already present in excess in the surrounding water, thus practically maintaining their normal resistance to heat. Death from high temperature appears to result from the accumulation of CO_2 in the tissues and not to asphyxiation or to hydrogen-ions in the surrounding water.

In another series of experiments Mayor found that the rate of nerve-conduction in *Cassiopea* tissue deprived of muscles may be the same as in tissue possessing muscles. In other words, the rate of the pulsation-wave in *Cassiopea* is determined by the nerve-net, not by the presence or absence of subumbrella muscles. Another research by Mayor at Tortugas was upon the rate of nerve-conduction in *Cassiopea* placed in sea-water deprived of its absorbed air. Rings of *Cassiopea* were placed under an air-pump, and it was found that the rate of nerve-conduction remained normal when the oxygen-supply was reduced to 20 per cent of the amount found normally in sea-water. Further reduction causes a progressive decline in rate, but nerve-conduction continues until the oxygen is reduced to 5 per cent, its normal amount.

In another set of experiments at Tortugas, Mayor found that holothurians (*Stichopus*) of average size may dissolve at least 414 grams of limestone sand per annum in their intestines; but further observations are required before a well-established figure for this loss of limestone over reef-flats is ascertained.

Professor Asa A. Schaeffer found 5 new and 5 imperfectly known species of salt-water amœba at Tortugas. He also carried out physiological experiments and determined the ability of these forms to withstand fresh or brackish water, as will appear in his report published herewith.

Dr. R. C. Wells made a direct determination of the CO_2 content of Tortugas sea-water, confirming McClendon's observation that in shallow water the CO_2 content is greater at night than in the day, the carbon being consumed by plants in photosynthesis. Details appear in his report published herewith.

Studies of the hydrogen-ion concentration of the surface-water of the Atlantic and Pacific were continued by Mayor, and these support his previously expressed conclusion that the counter-currents moving to the eastward over the surface of the equatorial Pacific consist of water which has come to the surface from a depth of at least 200 fathoms. The water of these easterly currents is relatively acid and gives out

CO_2 to the atmosphere. In general, however, the CO_2 tension of the surface waters of the Tropical Ocean is slightly higher than that of the atmosphere, while in the cold seas the CO_2 tension of the surface-water is below that of the air. Thus the colder waters are receiving CO_2 from the atmosphere, while it is escaping from the sea over the wide belt of the tropics.

On September 10, 1919, a severe hurricane passed over Tortugas, seriously damaging the wharf, the two main laboratory buildings, and the machine shop, and throwing down the windmill, as well as destroying the cages which contained the cerions being experimented upon by Dr. Bartsch. According to the U. S. Weather Bureau, the barometer was 28.83 at Key West and 27.57 at Tortugas, these being the lowest yet recorded from these regions. The damaged buildings will be repaired as soon as is practicable.

It is a pleasure to express the appreciation of the Department for the kindness of the British Embassy in Washington in providing the Director with a letter to the Governor of Fiji, and we are also indebted to Hon. Josephus Daniels, Secretary of the U. S. Navy, for a letter to the newly appointed governor of American Samoa, who was, however, our old friend Commander Warren Jay Terhune, who courteously aided us in every way. We are also similarly indebted to the United States Department of State for a letter to American consuls in the Pacific.

Quarantine regulations incident to the epidemic of influenza and a deficiency of steamers made it impossible to visit Fiji this summer, but we intend to go there in 1920 in order to ascertain the growth-rate of alcyonaria and corals planted out on the barrier reef off Suva in August 1918, and to make a detailed study of various features of the reefs.

Volumes IX and XII of Papers from the Department of Marine Biology were published during the past year. These contain 620 pages and 124 plates.

The following papers resulting from studies carried out under the auspices of the Department of Marine Biology were published by agencies other than the Carnegie Institution during the year:

HARVEY, E. N. 1918. Reversibility of the photogenic reaction in *Cypridina*. Jour. Gen. Physiol., vol. 1, pp. 133–145.

——. 1919. Chemical nature of Cypridina luciferin and Cypridina luciferase. *Ibid.*, vol. 1, pp. 269–293.

MAYOR, A. G. 1918. The growth-rate of Samoan coral-reefs. Proc. Nat. Acad. Sci., vol. 4, pp. 390–393.

——. 1919. Detecting ocean currents by observing their hydrogen-ion concentration. Proc. Amer. Phil. Soc., vol. 58, pp. 150–160, 1 fig.

Origin of Beach-rock, by Reginald A. Daly.

Local cementation of beach-sand by calcium carbonate is very common in Florida as well as in the tropical seas generally. The product may be called "beach-rock." It includes some of the Florida coquina limestone. The writer was invited to study the conditions under which this type of lithification takes place. His field-work has been confined to the Tortugas, the keys and mainland of Florida, and to six of the Samoan Islands. He found that beach-rock occurs only on shores subject to heavy surf and directly fronted by detrital flats which are shallow enough to be eroded by hurricane waves. The upper limit of beach-rock is the sea-level at high spring tide; the lower limit is usually, if not always, less than about 3 feet below sea-level at the low springs. The original sand may be purely calcareous, but in many cases sand-grains, cobbles, or large bowlders of lava or other siliceous material are important constituents. An extreme case, wherein the original sand is nearly pure olivine, was discovered in Tutuila, Samoa.

Until the laboratory studies are completed, a definite conclusion as to the origin of beach-rock is deferred, but, among the various hypotheses suggested by the facts, one looks specially promising. Ordinary beach-sand is comparatively clean. Sand torn up from an offshore flat and piled on the shore by a hurricane is necessarily charged with much organic matter, the subsequent decay of which would generate alkalies. It seems possible that the alkalies would cause the interstitial deposition of cementing calcium carbonate from the water circulating with each tide through the porous sand. To test this hypothesis experimentally, offshore bottom material was buried at the appropriate depth on the beach of Loggerhead Key, Tortugas. Typical beach-rock was there formed, by the year 1912, in the sand piled up during the hurricane of 1910. However, the hurricane of 1919 has torn up the buried material, hindering an experimental test in the near future. It may be noted that the hypothesis stated does not exclude the favorable consideration of other factors, but their discussion is postponed until the preparation of the final report.

While in Florida, the field facts bearing on the chemical deposition of calcium carbonate in the form of mud were also studied, with the conclusion that special attention should be devoted to the activity of eel-grass and other sea-weeds as an indirect cause for the precipitation of the carbonate from the saturated sea-water solution.

The Geology of American Samoa, by Reginald A. Daly.

The islands known as American Samoa consist of Tutuila with its satellites, Aunuu, Cockscomb (Pola), and a number of islets; Tau, Olosega, and Ofu, together forming the Manua group; and Rose Island. Excepting the last named, which is an atoll, all the islands of Samoa, including British Samoa (Upolu, Savaii, and their satellites), are volcanic.

The geological investigation consisted of a somewhat detailed mapping of Tutuila and reconnaissance of all the other volcanic islands of American Samoa. Six days were spent at Upolu; lack of time and of transportation prevented a visit to Savaii. The work was greatly facilitated by the use of excellent unpublished contour maps of Tutuila and the Manua group. Photographic copies of the manuscript maps, on the scale of 1 to 40,000, were kindly supplied by Dr. G. W. Littlehales, of the Hydrographic Office at Washington.

The Samoan chain of volcanoes is strikingly like the better-known Hawaiian chain. The products and mechanism of eruption largely correspond in the two groups. In principle Savaii is a close duplicate of its namesake, Hawaii; Ofu and Olosega are remnants of a single island which has lost much of its substance by downfaulting, as at Molokai; Tutuila recalls the much dissected

Kauai; Upolu has some of the essential features of Maui, though lacking the incomparable Haleakala.

Comparison of the degrees of dissection by streams shows that Tutuila is the oldest of the Samoan Islands. The core of Upolu may be as old, but its deeper valleys have been partly buried under newer floods of basaltic lava. Tutuila itself was not built up by continuous eruption, for on the south shore near Leone mature valleys cut in deeply weathered (lateritized) basaltic flows have been flooded with olivine-rich basalts of almost ideal freshness. Resting on these recent, broad flows, southeast of Leone, are two tuff cones with wide craters now forming bays separated by Steps Point. Aunuu Island is a tuff cone bearing a crater lake and is nearly of the same age. Tau, to the east of Tutuila, like Savaii on the extreme west, is young, and there stream-carving has only begun. Olosega and Ofu are more lateritized, but dissection is not much more advanced. Thus there is no regular increase of age in the islands from west to east, as inferred by some students of the charts.

For lack of fossil evidence, the geological dates of the eruptions can not be given. Tutuila has lost so much substance by erosion that the bulk of its lava-flows must be referred to a stage of the Tertiary period more than a million years ago. The age of the younger flows on Tutuila can hardly be more than a few thousand years, and it is probable that all the other Samoan islands are composed of, or veneered by, lavas of post-Tertiary dates.

Until microscopic examinations are made, no more than a general statement as to the classification of the rocks collected is possible. Tutuila is chiefly composed of flows, agglomerates, and tuffs of basalt, which is generally, though not always, free from conspicuous olivine. With these are associated flows of apparently andesitic habit and others of trachydoleritic habit. These are cut by many trap dikes and by much larger bodies—necks and huge, dike-like masses—of alkaline trachyte, probably true phonolite, and a type which seems to be the "syenitic nephelite basanite" of Weber and Friedlaender. The summit of the dominating peak, Matafao (elevation, 2,141 feet) is composed of alkaline trachyte or phonolite filling a small elliptical neck or vent through a thick mass of explosive products. Pioa (1,717 feet) is a much larger body of similar rock, a monolithic volcanic neck or crater-filling. Cockscomb Island is part of an intrusive phonolitic pod, about 7,000 feet long and 2,000 feet in maximum width. Smaller trachytic or phonolitic intrusions, either necks or thick dikes, were found on Papatele and at Afono Bay. The syenitic rock forms a pipe on the divide between Pago Pago and Fagasa Bays. The Tutuila eruptions took place in the following order: (1) basalt, andesite (?), trachydolerite (?), in flows, breccias, tuffs, and dikes; (2) trachyte, phonolite, in dikes and volcanic pipes; (3) olivine-rich basalt (Weber's "limburgite"), flows of the Leone district; (4) basaltic tuffs and agglomerates of the lateral craters.

Erosion has been clearly controlled by the relative strengths of these rocks. The special resistance of the trachyte and phonolite to the weather explains the bold projection of the peaks and ridges of Matafao, Pioa, Papatele, Afono Bay, and of Cockscomb Island and the heights to the southwestward. Many spurs and capes are ribbed with massive dikes of trappean basalt and other rock types. The valleys have been sunk in the weaker lava-flows and the still weaker pyroclastics. In other words, a notable part of the Tutuila drainage is adjusted to the softer structures throughout the eastern two-thirds of the island, where constructional forms have been almost completely obliterated. On the other hand, in the axial region north and northwest of Leone, the original lava-flow surface is still preserved as a plateau with an area of more than a square mile. In that region the lavas may be slightly younger than those constituting the greater part of Tutuila, but the edges of the plateau are dissected by valleys reaching 700 or more feet in depth. The

erosion of the very recent lavas between Nuu'uli and Leone has just begun. The history of Pago Pago Bay, the chief harbor of American Samoa and one of the noblest in the Pacific, presents a special problem, the discussion of which is postponed.

The detritus resulting from the deep erosion of Tutuila was built into an encircling offshore shelf, the edge of which is now in general 2 to 3 miles from the headland cliffs of the island. Near that edge an interrupted barrier coral-reef was formed. Presumably fringing reefs were contemporaneously developed. Then Tutuila sank by a differential movement, so that the crest of the barrier reef is now from 30 fathoms to a few fathoms below sea-level. Accordingly, the shelf inside that reef is covered with water reaching a depth of 60 fathoms, or more than twice that ruling in typical barrier-reef lagoons of similar breadth. The subsidence also helps to explain the numerous embayments due to the drowning of valleys.

Prolonged special study has confirmed Mayor's conclusions that when the sea stood at its higher level, corals were not growing on the shores of Tutuila, and that reef corals were absent during the time required to cut the modern cliffs on all headlands and even in the shallower bays. The cliffs reach 300 or more feet in height. After their cutting the sea-level sank about 20 feet New clifflets were cut at the new level, but protection from the surf was soon furnished, at most of the headlands, by the very recent growth of fringing reefs, which at the same level are now growing outwards. They have attained, however, widths usually less than 600 feet and are much narrower than most fringing reefs in the Pacific.

The evidence for the 20-foot shift of sea-level is founded on the fact, already noted by Mayor, that on all sides of Tutuila the headlands are faced by wave-cut benches with summits approximately 8 feet above present high-water level. Since similar benches, now being cut by the waves, are covered by 10 to 15 feet of water about tide, it is necessary to place the high-water level, just before the last shift, about 12 feet above the bench crest-level. Corroboration of this view was found in the discovery of large sea-caves with floors at appropriate heights (14 to 15 feet) above high tide.

Wave-cut benches at exactly similar levels were found on Aunuu Island and on Tau Island, which is 60 miles from Tutuila. Recent downward shifts of sea-level of the same order of magnitude have been reported from many other Pacific islands, as well as from the east coast of North America and elsewhere. A compilation of these facts suggests that the last downward shift of sea-level in Samoa is eustatic, world-wide, due to an independent lowering of the ocean surface everywhere. The alternative hypothesis, that the shift was local, because controlled by uplift of the islands, is highly improbable, for vertical movements of the earth's crust are not likely to be uniform at many points, some of which are 60 to 75 miles apart—much less at points hundreds of miles apart, as in the Gulf of St. Lawrence and along the eastern coast of the United States.

It may be added that there is no conclusive evidence of uplift anywhere in Tutuila. Friedlaender reported elevated limestone 20 meters above sea at two localities in the eastern part of the island. Careful search showed no trace of limestone at these localities, though at one place coral-heads have been carried up by the natives from the reefs to and beyond the height mentioned.

New light was thrown on one cause for the subsidence of volcanic islands; repeated observations showed that the scoriaceous and "aa" phases of the Samoan lava-flows have been crushed and compacted by the weight of younger lava-flows and pyroclastics. As long as this process continues in depth, the surface of the volcanic pile must tend to sink.

Due to local sinkings on a grand scale, an island at one time almost as large as Tau was converted into the existing islands Ofu and Olosega. The southern third of the original island foundered beneath the waters of the Pacific, the downward movement taking place along a curved fault, the trace of which is convex to the north. In a similar way the northern third foundered, along a fault-line convex to the south. The two curves are practically tangent at the strait between Ofu and Olosega. The sharp spurs to east and west of the strait present ragged cliffs remarkably similar to the Pali, the famous fault-scarp of Oahu, near Honolulu. The writer suspects that a partial foundering may have cooperated in the formation of Pago Pago Bay in Tutuila.

The bearing of the season's work on theories regarding magmatic differentiation and the origin of coral-reefs will be discussed in the final report. On the present occasion the writer will merely state two major conclusions: Samoa illustrates once again the high probability that some alkaline trachytes and phonolites are derivatives of common basalt; and detailed study of the Samoan reefs confirms skepticism as to the validity of the Darwin-Dana theory of coral-reefs as a general explanation.

Determinations of the Carbon Dioxid in Sea-Water at Tortugas, Florida, by Roger C. Wells.

Having previously found it difficult to decide whether the CO_2 content of certain samples of Gulf water should be ascribed to its physical or organic history,[1] the writer welcomed the opportunity to make some further determinations at the Marine Laboratory at Tortugas in June 1919. The tests were made on water taken directly from the sea at various points about Loggerhead Key, at a depth of about a foot below the surface, and included determinations of the temperature, chloride content, excess base or alkalinity by titration, and the P_H value, as well as the total CO_2. The results are shown in table 1. The chloride was titrated with a solution of silver nitrate, using potassium chromate as indicator, and the density of the water as sampled was calculated by the aid of Knudsen's tables. The titrations were checked with gravimetric determinations and found to be correct. The P_H values were estimated colorimetrically by comparison with a set of standard tubes prepared for this purpose and very kindly loaned to the writer by Professor J. F. McClendon.

The excess base was obtained by titrating 100 c.c. portions with 0.02 normal sulphuric acid, using methyl red as indicator and blowing out the carbon dioxid by means of a stream of pure air for 15 to 20 minutes. Although the method gives good results, it is difficult to interpret them, as the alkali titrated includes a small amount due to substances other than carbonates and bicarbonates. Further determinations yielding only the normality of the carbonates and bicarbonates in the water are desirable, the latest determinations by the writer indicating a value of about 0.00223 for this quantity.

The total carbon dioxid was determined by adding an excess of hydrochloric acid to 500 c.c. portions of the water and boiling about 15 minutes, while a current of pure air was passed through the water, then over calcium chloride, and finally through weighed soda-lime tubes. A counterpoise was used in order to minimize errors likely to be caused by the high humidity.

No definite relations are apparent between the slight variations in the temperature and excess base, or between the variations of the total CO_2 and

[1] New determinations of carbon dioxid in water of the Gulf of Mexico. U. S. Geol. Survey Prof. Paper 120-A, p. 7, 1918.

the temperature, excess base, or condition of the tide, in this series of determinations. The total CO_2, however, shows an unmistakable diurnal variation, which is doubtless caused by photosynthetic action, as McClendon has pointed out.[1] During the day CO_2 is withdrawn from the water by plants, owing to the action of the chlorophyll, and the deficit is afterwards made up by animals, the respiration of plants, or by CO_2 from other sources. The average diurnal variation for 5 days was about 4.3 per cent of the total CO_2.

It is therefore evident that organic factors greatly affect the CO_2 content of the sea-water at Tortugas, if they do not wholly determine it.

TABLE 1.—*Determinations on sea-water at Loggerhead Key, Tortugas.*

[*t*, temperature, °C.; *Cl*, chlorine, grams per kilogram; *D*, density; P_H, hydrogen-ion concentration expressed as $-\log [H^+]$; *Alk.*, excess base, in terms of a normal solution, or alkalinity titrated with acid, using methyl red and blowing out CO_2; CO_2, total, gram per liter.]

	Date, time, and condition of water.	*t*	*Cl*	*D*	P^H+	*Alk.*	CO_2
1	June 10, 3^h30^m p. m.; cloudy...	26.6	20.01	1.02373	......	....	0.0890
2	11, 12 noon; fair..........	27 6	20.00	1 02339	......	0.002370	.0925
3	11, 5^h30^m p. m.; cloudy ..	28.2	20 05	1 02326	....	.002368	....
4	12, 12 noon; after rain. .	27 4	19.90	1.02332	8.23	.002398	.0902
5	13, 6^h45^m a. m.; after rain.	27 1	19 28	1 02258	8 19	.002394	.0924
6	13, 9 50 a. m.; cloudy...	27.1	19 90	1.02342	8.19	.002394	.0913
7	13, 12 50 p. m.; cloudy...	27.5	20 07	1 02352	8.21	.002410	.0900
8	13, 4 10 p. m......... ..	27.6	19 96	1.02334	8 20	.002402	.0897
9	14, 9 45 a. m.; after rain and wind..........	27 0	19.89	1 02344	8.19	.002406	.0881
10	14, 3^h45^m p. m.; wind....	27.4	19.87	1 02328	8 22	.002402	.0863
11	14, 5 15 p. m.; wind....	27.8	20 00	1 02333	8.21	.002412	.0873
12	15, 6 30 a. m.; wind....	26.5	19 94	1.02366	8 21	.002435	.0910
13	15, 11 a. m....	26.8	19 31	1 02371	8.21	.002424	.0869
14	16, 7^h10^m a. m.; fair.....	26 8	19 99	1.02368	8 07	.022368	.0904
15	16, 8 15 a. m.; fair......	27.0	20.00	1.02359	8.19	.002414	.0896
16	16, 11 a. m.; fair........	27.0	19 99	1.02357	8.20	.002440	.0888
17	16, 4^h15^m p. m.; fair......	28 1	20.05	1.02330	8.23	.002374	.0873
18	16, 5 45 p. m.; fair.......	27.8	19.98	1.02330	8.21	.002410	.0873
19	17, 6 30 a. m...........	27.1	19.99	1.02354	8.20	.002414	.0928
20	17, 10 15 a. m.; slightly cloudy............	27.3	20.09	1.02361	8 18	.002396	.0910
21	17, 4^h45^m p. m.; rainy....	26.8	19 16	1.02239	8.20	.002306	.0857
22	17, 7 p. m.; after rain ...	27 6	19 77	1.02308	8 19	.002326	.0893
23	18, 7^h15^m a. m.; after shower............	26 8	20 04	1 02370	8.18	.002418	.0918
24	18, 11 a. m.; rain.........	26 8	19.81	1 02339	......	.002400	.0928
25	18, 1 p. m.; rain.........	26 6	19 73	1 02334	.....	.002374	.0879

The average value of total CO_2 found was 0.0895 gram per liter at about 27.2° C., whereas the writer previously found 0.0952 gram per liter for water averaging 19.1° C., including some deeper waters, collected in the Gulf south of Pensacola. The Tortugas water appears to be slightly deficient in CO_2, from the standpoint of equilibrium with the atmosphere, if the other samples are assumed to be near the equilibrium requirements, as they seem to be when tested by the equation of Fox for the solubility of CO_2 in sea-water. In other words, the Tortugas water appears to be very slightly modified Gulf water.

[1] Diurnal changes in the sea at Tortugas, Florida. Proc. Nat. Acad. Sci., vol. 3, p. 692, 1917.

Investigations Regarding the Calcium Carbonate Oozes at Tortugas, and the Beach-Rock at Loggerhead Key, by Richard M. Field, Museum of Comparative Zoology, Cambridge, Massachusetts.

While enjoying the privileges of the laboratory of the Carnegie Institution of Washington, situated at Loggerhead Key, Tortugas, Florida, I had excellent opportunities for studying the conditions of bottom accumulation of calcium carbonate ("drewite") in the shallow lagoons and channels between the reef-flats. The weather was remarkably clear during the earlier part of my stay, so that the bottom could be studied over wide areas and samples collected with comparative ease.

These submarine calcium-carbonate deposits, heretofore called "coral muds," the precipitation of which Drew ascribes to the action of marine bacteria, are of particular geological interest. Whether or not they owe their origin to the action of bacteria, they bear a striking resemblance in chemical and physical properties to certain exceedingly fine-grained and unfossiliferous limestones of the Lower Paleozoic. I have particular reference to the purer limestones of the Stones River group in the Appalachian province.

I have studied the limestones of this group from New York to Tennessee and find that they are particularly characterized by such intraformational structures as desiccation-fractures, *i.e.*, "sun-cracks," "mud-cracks," ripple-marks, and glomerates. The origin of the latter I have attributed to breaking-up of the desiccated, fractured zone and the molding and redeposition of the still plastic phenoclasts by the action of tidal currents or waves. This hypothesis has been substantiated by the action of the fine-grained, bacterially precipitated calcium-carbonate mud from Tortugas, which was discovered to be of a particularly plastic nature, rapidly developing desiccation-fractures when exposed to the air, and capable of producing all of the inorganic intraformational structures which I had previously studied in the Stones River group.

Experiments have proved that this plastic carbonate ooze hardens very rapidly when exposed to the air. Desiccation-fractures are not destroyed when the surface bearing them is flooded with salt water mixed with fresh ooze. The ooze filters in between the cracks in the older, sun-baked surface, and thus a series of superimposed, mud-cracked zones can be formed experimentally which, in cross-section, are in every way similar to those in the Stones River formations. Furthermore, the phenoclasts resulting from the desiccation of the ooze may be readily shaped into pebble-like forms, which upon redeposition and lithification would have the appearance of a true basal conglomerate, in spite of the fact that they had been formed almost simultaneously, geologically speaking, with the deposition of the primary ooze itself. The significance of this fact, when applied to the study of physical evidences of disconformities within the carbonate rocks of the Palaeozoic formations, can not be overestimated.

The general geological aspects of the Stones River limestone point rather strongly to conditions of sedimentation similar to those of the coral-reef latitudes of the south Atlantic, and especially off the southern coast of Florida and the west coast of the Bahamas.

The "beach-rock" or "coquina" which is apt to encircle the shell-sand keys of the Tortugas group has already aroused some discussion as to its mode of origin. I have studied the "beach-rock" at Loggerhead Key, and although I have not yet fully proved my premises by experiment, it appears as if the phenomena can be accounted for as follows:

The rock is obviously formed from the same material as the key, except that in the case of the former the shell-sand is more or less loosely cemented

together. The rock is particularly free from carbonaceous matter or impurities of any kind, and so closely resembles the clean beach-sand as to be indistinguishable from it, except for the matter of cementation. On the other hand, the bulk of the key sands is discolored by large amounts of carbonaceous material. The "beach-rock" seems to occur only between high and low water (maximum difference approximately 2.5 feet), and is so rapidly disintegrated by the waves and marine organisms that it would soon cease to exist unless covered and protected or *periodically reproduced.* Where the shape of the beach is subject to change by wave and current action, no rock is formed. In 1912 Dr. Vaughan observed that "beach-rock" is now exposed near the landing-stage at Loggerhead Key, where once was a depth of several feet of water, showing conclusively that the rock has been formed since the hurricane of October 17, 1910, swept the shell-sand into place.

By means of a pump and standpipe, the latter sunk some distance back from the beach, I was able to prove that the shell-sand of the key was particularly porous to a depth of at least 14 feet (several feet below low tide-level) and that the sea-water passes through the island to the extent that it is even affected by the slight rise and fall of the tide.[1]

During a two days' heavy rain the water was found to stand considerably higher in the standpipe. It is reasonable to suppose that in the case of an exceedingly heavy rain, such as must take place during a tropical storm, the key would remain saturated with rain-water having an acidity approaching PH 4.75 before its contact with the sand. The acidity of the pure rain-water, however, would be increased by the humus acid in the key sands, as the water percolated through them.[2]

In case of very heavy rain, the key would act like a huge sponge, the ground-water level being raised nearly, if not quite, to the surface. After a two days' rain the water from the driven pipe was tested and found to contain just twice as much $CaCO_3$ in solution, or colloidal form, as the sea-water.

My theory is that after an exceptionally severe storm, during which fresh sand is swept upon the beach in places and the beach itself scoured in others, the bulk of the key sands above tide-water level are saturated with a strong solution of calcium carbonate. This solution continues to trickle out through the *beach* sands, at ground-water level, for several days, and upon exposure to the air deposits calcium carbonate in the spaces between the bits of shell, thus forming the "beach rock." The precipitation of the $CaCO_3$ is probably due to the relief of pressure, the escape of Co_2, and the consequent lowering of the solubility of the $CaCO_3$. The fact that the "beach rock" can not owe its origin to the action of putrifying matter in place, such as seaweeds, etc., is, I believe, proved by the total absence of any carbonaceous material in the rock itself.

Researches on the Production of Light by Luminous Animals, by E. Newton Harvey.

My previous researches on light production in *Cypridina*, a luminous crustacean, reported in the 1917–18 Year Book, led to the conclusion that luciferin, the oxidizable material of *Cypridina*, is in all probability related to the peptones, while luciferase, the catalyst in whose presence luciferin oxidizes with

[1] The superintendent of the Light-House Board, Mr. Putnam, assures me that he is unable to find any record of the material encountered when the excavation was made for the foundation of the light-house at Loggerhead Key.

[2] The dissolving power of the humus acid is probably more highly effective than that of pure rain-water alone. At any rate, both have a more solvent action upon the beach-sands than ordinary sea-water. The PH of normal sea-water is 8.2. The PH of the "pipe water" was found to be 7.85, the decrease in acidity being due to the dissolved $CaCO_3$. Water with a PH higher than 7 will not dissolve limestone.

light production, is probably an albumin or very closely associated with an albumin. Evidence was also presented to show that the oxidation product of luciferin, which I called oxyluciferin, has properties similar to luciferin itself and represents only a slight oxidative change, not a fundamental splitting of the luciferin molecule. The oxyluciferin can be readily reduced to luciferin again by various reducing agencies, among them the nascent hydrogen produced by action of acids on metals. Acid favors the reduction of oxyluciferin, and alkali favors the oxidation of luciferin.

Thanks to the kindness of Professor C. Ishikawa, of the Agricultural College, Imperial University of Tokyo, Japan, I have received an additional supply of *Cypridina* material, with which the researches have been continued. My present research deals with the action of acids in facilitating reduction of oxyluciferin, the possible production of CO_2, and of heat during oxidation of luciferin, and the general nature of the luciferin$\rightleftarrows$oxyluciferin reaction.

Carbon dioxid production was tested by determining if any change in acidity, which might come from CO_2 produced, occurs when solutions of luciferin and luciferase are mixed. After several attempts to measure acidity by adding an indicator (thymol-sulphone-phthalein) to the solution, this method was given up because the luciferin and luciferase solutions are yellowish in color, which interferes with the yellow-blue color change of the thymol-sulphone-phthalein. The electrometric determination with the hydrogen and N/10 KCl calomel electrode is the most sensitive. A McClendon electrode and a Leeds and Northrup potentiometer were used. The acidity of the luciferin solution, luciferase solution, and the two after mixing was found to be the same, $P_H=9.04$. Therefore, not enough CO_2 is produced to affect the H-ion concentration.

As both luciferin and luciferase solutions contain proteins, and as luciferase is certainly and luciferin probably a protein, it will be seen that their buffer value is relatively high. The luciferin and luciferase solutions, although prepared with distilled water, no doubt contain also a small amount of buffer salts. Our experiments show this much, however, that not enough CO_2 is produced during luminescence to saturate the proteins in solution, including luciferin and luciferase themselves. The reaction responsible for luminescence, the oxidation of luciferin, is therefore not to be compared to the reactions in cells giving rise to the carbon dioxid of respiration.

The production of heat during luminescence was determined by bringing solutions of luciferin and luciferase to the same temperature and then mixing them. One can thus measure any increase or decrease of temperature which occurs during the luminescence which results from mixing, and gain some idea of the heat of oxidation of luciferin. Although the experiment sounds very simple, it is actually somewhat difficult to carry out. After many attempts it was found necessary to bring the luciferin and luciferase solution to temperature equilibrium in two separate tubes within one thermos bottle, and to mix the solution by breaking the tubes. Two thermo-couples of copper advance wire were used to measure the temperature—one in the luciferase, the other in the luciferin solution. These were connected through a copper double-throw switch with a galvanometer of a sensitivity such that 1 mm. deflection represented a temperature change of 0.003° C. As mixing the solutions heats them slightly, control experiments with water in each tube were carried out.

With both control (water) and luciferin experiments there was a slight rise in temperature on mixing the liquids in the two tubes. The average rise of 5 control (water) experiments was 0.0054° C. and the average rise of 5 luciferin experiments was 0.0048° C. The difference in the average rise of control and of luciferin experiments is so small (0.0006° C.) as to have little significance.

We may therefore conclude that if any temperature change occurs during the luminescence reaction it is certainly less than 0.001° C., and probably less than 0.0005° C., too small to be measured by this method.

To prepare the luciferin solution, 2 grams of dried *Cypridina* were dissolved in 20 c.c. hot water and 10 c.c. of this 10 per cent solution were used in the thermos bottle in the above experiments. If we assume that 1 per cent of the dried *Cypridina* is luciferin, 0.1 gram of luciferin on oxidation was not able to raise the temperature of the 10 c.c. (in reality 11 c.c., since 1 c.c. luciferase solution was mixed with the 10 c.c. luciferin) of solution 0.001° C. This means that 1 gram luciferin liberates at least less than 0.1 calorie during the luminescence accompanying oxidation.

It is because of the small energy change during oxidation of luciferin that the reaction may be so easily reversed and oxyluciferin reduced. Most of the reducing methods described in my last report involve reduction in acid solution or in a solution which becomes acid. Indeed, acid alone will cause a slight reduction, and this is a function of the H-ion concentration, since any acid added to oxyluciferin will cause a slight reduction to luciferin. The change begins when the solution is about neutral, $P_H = 7.1$. Acid is not essential for reduction, however, as reduction can occur in alkaline solutions which generate nascent hydrogen, as on addition of Al and NaOH, or merely on mixing oxyluciferin with finely divided Al, Zn, or Mg, or in the presence of $(NH_4)_2S$.

Since all the reducing methods which may be used with oxyluciferin will also reduce methylene blue to its leucobase, I believe we may provisionally use this reaction as a type to explain what happens when luciferin is oxidized. As methylene blue contains no oxygen, its reduction consists in the addition of 2 atoms of hydrogen. When leuco-methylene blue oxidizes, which it does spontaneously in air, water is formed by the union of these 2 atoms of hydrogen with oxygen, thus:

$$C_{16}H_{20}N_3SCl \text{ (leuco-methelene blue)} + O \rightleftarrows C_{16}H_{18}N_3SCl \text{ (methylene blue)} + H_2O$$

For short,

$$MH_2 + O \rightleftarrows M + H_2O$$

Writing the luminescent reaction in a similar way, we have:

$$\text{luciferin} + O \rightleftarrows \text{oxyluciferin} + H_2O.$$

For short,

$$LH_2 + O \rightleftarrows L + H_2O.$$

If we assume that the LH_2 (luciferin) compound is dissociated to even the slightest extent into L and hydrogen, adding the hydrogen ion will shift the equilibrium toward the formation of that substance which involves the taking up of hydrogen. Consequently, we may obtain a partial formation of luciferin by adding an acid to oxyluciferin. Reduction of the H-ion concentration tends to shift the equilibrium in the opposite direction. Consequently, addition of alkali favors the oxidation of luciferin, and it is quite generally true that biological oxidations are favored by an alkaline reaction. In addition, oxygen in alkaline medium has a higher oxidation potential than in neutral or acid media. I believe that this is the explanation of the action of acid in formation of luciferin from oxyluciferin.

Addition of acid is not the only means of favoring the formation of luciferin from oxyluciferin. Any reaction which proceeds in one direction with evolution of light should, theoretically, proceed in the opposite direction under the influence of light. It is a fact that light will cause the reduction of oxyluciferin. A tube of oxyluciferin exposed to sunlight for 6 hours or the mercury arc for 2 hours will be partially converted into luciferin. It will lumi-

nesce when luciferase is added, while a control tube kept in darkness shows no trace of luciferin. The action is more marked with the ultra-violet, as a solution of oxyluciferin in a quartz tube showed more reduction than one in a glass tube when exposed for the same length of time to the quartz-mercury arc. The reduction is not dependent on the formation of acid under the influence of light, since two tubes of oxyluciferin, one kept in darkness and the other exposed to sunlight for 6 hours, had the same reaction, $P_H = 9.3$. Of course, some reducing substance might be formed under the influence of light, but this is not very probable.

We may therefore write the reaction for luminescence in *Cypridina* in the following way:

$$\text{luciferin } (LH_2)+O \underset{\substack{\text{perhydridase (a reducing enzyme) or nascent H} \\ \text{acid} \\ \text{light}}}{\overset{\substack{\text{darkness} \\ \text{alkali} \\ \text{luciferase}}}{\rightleftarrows}} \text{oxyluciferin } (L)+H_2O \text{ (luminescence)}$$

Report of Additional Observations and Experiments upon Problems of Animal Coloration, by W. H. Longley.

The interval between June 5 and July 3, 1919, was spent at Tortugas in continuation and extension of my previous investigation in the field of animal coloration. For the privilege of continuing my work for a time after the formal closing of the Laboratory I am particularly grateful.

Attention has been called in a previous report to several pairs of closely related species in which a specific sort of difference in coloration is correlated with a definite difference in behavior. *Abudefduf sordidus* and *Chromis elaphrus* are bottom-haunting Hawaiian fishes of dusky or yellow-olive shades, without trace of the blue or blue-gray which is so conspicuous an element in the coloration of *A. abdominalis* and *C. ovalis*. The two species last named habitually swim high in the water, where their blue-gray pigments reduce their visibility from the point of view of an observer at a lower level.

In this connection it is interesting to note that the same difference in behavior occurs in the case of *Abudefduf taurus* and *A. saxatilis*, which are quite similar in appearance to *A. sordidus* and *A. abdominalis* respectively, and, in a sense, replace them in the Tortugas fish fauna. *Teuthis hepatus* and *T. cæruleus* are likewise a pair of related species in which the predominantly olivaceous and blue types of coloration appear in correlation with the specified difference in habit.

These facts simply emphasize the general conclusion that the interpretation to be placed upon the *color* of animals should be sought through study in detail of their relation to their environment.

Regarding the significance of *pattern*, the most suggestive observation made during the summer referred to the squid, *Sepia* sp.

The coloration of this small cephalopod, like that of some others at least, is almost incredibly fluid. It is now dark brown, now exceedingly pale; now longitudinally striped, now transversely banded. One does not encounter the creatures frequently under water, but one at least of their changes in appearance occurs so regularly that it requires only a few moments to determine the system followed. When swimming, the squid is longitudinally striped; when, except for the rippling motion of its lateral fins, it is at rest, it is transversely banded. This, however, is exactly the rule which certain fishes follow, which, like the squid, have alternative striped and banded color phases.

Fishes and cephalopods have independently developed eyes the mechanical principle of whose construction is essentially the same. One is entitled to suppose that in the two cases this is due to common adjustment to the same underlying reality, the nature of light and its mode of operation. The combination of lens, dark chamber, and sensitive surface is one of the most efficient, if not quite the most efficient, system upon which an image-forming eye might be constructed, of which fact fishes and cephalopods, so to speak, bear independent witness.

Similar adjustment to underlying reality of some sort may be inferred with justice wherever convergent evolution occurs with respect to characters which there is real reason to believe are of service to their possessors. Much evidence has already been presented[1] tending to show that the coloration of fishes at least is obliterative in effect. It therefore seems fair to conclude tentatively that the convergent evolution of fishes and some cephalopods in respect to pattern-display indicates the existence of laws of optical illusion to which the color-patterns of animals tend to conform.

The hypothesis that fishes, for example, have in course of time become obliteratively colored through natural selection, involves the assumption that they are preyed upon by other animals of more or less keen powers of discrimination habitually exercised. Hence preliminary experiments were undertaken with the object of determining to what extent a fish of such apparent intelligence as the gray snapper might conceivably exert bionomic pressure to modify the color or form of fishes or crustacea among which it lives and upon which it feeds voraciously. The time available for this work was so strictly limited, however, that while the results obtained are interesting, they are of present value chiefly as they suggest promising modes of attack upon the problem.

When the weather permitted, the work of photographing the fishes in their natural surroundings through use of diving apparatus and camera specially fitted for submarine work was continued with most gratifying results. Twenty additional pictures were secured showing fishes characteristically engaged, the detail in a number of which is scarcely to be surpassed in photographs taken on land.

The Effect of Anesthetics on Basal Metabolism, by J. F. McClendon.

Owing to the difficulties in keeping metabolism down to the basal level in higher animals, comparative studies in metabolism upon forms in which this can be done are desirable. In choosing an animal for such investigations, the jellyfish *Cassiopea xamachana* was decided on, since the automatic activity of the nervous system may be abolished by cutting off the margin of the bell and the respiration-rate is independent of oxygen tension, except for very low tensions of oxygen.

In determining the rate of metabolism, 4 jelly-fish of large size (up to 15 cm. diameter) were deprived of manubrium and bell-margin and placed in sea-water in an air-tight jar of about a liter capacity and rotated in a thermostat at 30° for 1 hour. The oxygen used was determined by the Winkler method and the CO_2 given out was calculated from the alkaline reserve and changes in the hydrogen-ion concentration (expressed as PH). It was found that the neuro-muscular system in the bell was anesthetized with 0.5 per cent ether in sea-water, whereas the jelly-fish died at the end of 1 hour in 3 per cent ether and in less than an hour in 4 per cent ether. The respiratory quotient was found to be about 0.95, and since the CO_2 determinations were less accurate

[1] Journ. of Exp. Zool., Aug. 1917, and previous reports in this Year Book.

than those for oxygen, only the latter are given in the following table. The jelly-fish were tested 1 hour without anesthetic as a control.

Ether.	With anesthetic.	Control.
0.5 p. ct...	2.35 c.c. O_2	2.4 c.c. O_2
1 p. ct...	2.4	2.4
Do....	1.8	1.8
Do....	2.7	2.65
2 p. ct...	2.2	2.1
3 p. ct...	1.2	1.2
4 p. ct...	1.2	2.05

It may be seen from the above table that, within the limits of error of the method, the oxygen consumption was the same with or without ether up to 4 per cent ether, in which case death occurred before the end of the experiment. Whether this is general for all anesthetics could not be determined, owing to limited time and the fact that some anesthetics interfere with the Winkler method. Carbon dioxid is sometimes considered an anesthetic, and the following experiments were made by adding it to sea-water and then estimating the total CO_2 content from the alkaline reserve (0.025 N) and the P_H (mean between P_H at beginning and end of experiment).

From the above table it may be seen that the metabolism is progressively lowered with the addition of CO_2 to the sea-water. The question arises whether the CO_2 found as bicarbonates and carbonates is effective. In order

Control (P_H = 8.15).	+ CO_2.	
2.08 c.c. O_2	2 c.c. O_2,	P_h=6.6
2.02	1.85	6.3
2 6	1.6	5.8
1.7	0 4	5.5
1.7	0.7	5.7

to study this, another series of experiments was made by adding HCl to decompose these salts, but without addition of CO_2 gas to the sea-water, as follows:

Control.	+ HCl.	
2.07 c.c. O_2	2.02 c.c. O_2,	P_H=6.6
1.85	1.3	5.85

It may be seen from the above table that CO_2 liberated from the salts of sea-water lowers the metabolism. In order to test whether the hydrogen-ions derived from hydrolysis of CO_2 had the depressant effect, sea-water was deprived of CO_2 after exactly neutralizing the alkaline reserve with HCl and then acidified with a few drops of phosphoric acid. In the control the jelly-fish used 2.9 c.c. O_2, and in the CO_2-free sea-water of $P_H = 5.9$ they used 2.7, which difference is within the limit of error. We may therefore conclude that the P_H is not the controlling factor, but that CO_2 lowers the metabolism.

Investigations on the Specific Characters of Marine Amœbas at Tortugas, by A. A. Schaeffer.

This investigation on marine amœbas was prompted by the fact that there is an almost total lack of information concerning these organisms, both from the systematic and from the experimental point of view. During May and June 1919, 5 new species were isolated and described from the waters in the neighborhood of Tortugas, Florida, and an equal number of species were found whose specific descriptions are still, for one reason or another, incomplete. Further data on these amœbas will be published later.

The amœbas were obtained in the following ways: (1) By towings of the surface-water in the vicinity of Loggerhead Key, especially in shallow water. A small number of individuals of several species were always found in these towings. (2) By washing floating and submerged seaweeds (*Sargassum, Halimeda*) and eel-grass. The sediment from these washings always yielded a considerable number of amœbas of various species. *Sargassum* brought to the shore by a southeast gale of several days' duration carried one large species of amœba which was not found under other circumstances. (3) By cultures in glass dishes made up of sargassum and other seaweeds and eel-grass, with or without a small quantity of finely ground timothy hay, and normal sea-water. Through some of these cultures a very slow stream of water was kept running. Some of the dishes were covered to prevent evaporation, while others were left uncovered. Certain species grew very readily in these cultures. (4) By filtering a slow stream of sea-water through cheese-cloth holding a small wad of cotton. This method yielded the largest variety of species, but the number of individuals of any species was small.

Excepting the fact that contractile vacuoles are lacking in marine amœbas, these organisms do not differ in their general characteristics from fresh-water amœbas. Some of the marine amœbas possess actoplasmic ridges such as are found in the fresh-water *Amœba verrucosa* and its congeners. Vacuoles in large number are often seen in marine amœbas, and in rare instances a vacuole may be observed to disappear slowly. But such cases of disappearance are probably not to be interpreted as physiologically similar to the functioning of a contractile vacuole. The general characters associated with streaming—pseudopod formation, rate of movement, formation of food-cups, and so forth—are similar in both fresh and salt-water amœbas.

It is especially worth noting that during active locomotion the outer or surface layer of the marine amœbas moves forward over the ectoplasm in the same way as the surface layer of fresh-water amœbas is observed to do. It is also of importance to know, especially from the point of view of systematics, that optically active crystals occur in some species of amœbas living in the sea, for, as I have shown in previous papers, the crystals form one of the most constant and dependable characters known to these organisms. Unfortunately for systematics, less than half of the number of marine species thus far described possess crystals. It is perhaps worth noting, also, that endoplasmic inclusions of all sorts—vacuoles, nucleus, protoplasmic granules, etc.—are much less conspicuous in salt-water amœbas than in those living in fresh water; but this difference is due undoubtedly to the purely physical effect of the salt-content of the water, for when marine amœbas are placed in fresh water, these inclusions become more refractive to light and consequently more conspicuous.

One of the chief objects of this investigation is to learn something of the distribution of marine amœbas in the waters of the earth and of the factors which control such putative distribution. This being the first recorded attempt in the investigation of this problem, such data as have been obtained on this point become of importance, however, only when compared with similar

data obtained in other localities. But some observations have been made which indicate that the problem of distribution is a practical one to investigate. It has already been noted, for example, that several species of amœbas found on floating sargassum from the Gulf Stream were not found on the seaweeds growing near the shore-line. More important in this connection is the fact that 4 of the 5 amœbas described feed principally on bacteria, and they consequently occur most abundantly where vegetative or animal matter is undergoing disintegration. These species are therefore distributed, at least to some degree, in accordance with the quantitative distribution of bacteria. Another observation of importance in the study of distribution is the degree of resistance which different species of amœbas show toward varying concentrations of the salt-content of sea-water. Two of the species described are resistant to immersion in fresh water for a considerable period of time (10 minutes), while another species loses all power of movement in 50 per cent sea-water and dies in 25 per cent sea-water. The former two species evidently may live in brackish water, while the latter species can not. Again, one of the species can live and move in concentrated (364 per cent) sea-water as well as in fresh water, while other species shrivel up and disintegrate in such highly concentrated water. The former species may therefore conceivably live in some inland seas whose waters contain a high percentage of salt, while other species seem to be more or less closely adjusted to the amount of salt found in the water of the ocean. The species that can withstand fresh water as well as 364 per cent sea-water might therefore be expected to be found living in fresh water occasionally in natural conditions. Such does not seem to be the case, however, for this species has never been reported from fresh water. In fact, no species of amœba is known that lives naturally both in fresh and salt water. The distribution of amœbas over the world appears, therefore, to be determined by a number of factors.

The difference various species of amœbas show in their resistance to sea-water is always of the greatest importance in defining the species and in readily recognizing them, for the number of definite and readily recognized constant characters in amœbas is very small. The probability is strong that any species of amœba may be characterized by a definite degree of resistance of its surface-layer expressed quantitatively in terms of concentration of sea-water.

This preliminary survey of the marine amœbas indicates that the sea is at least quite as rich in these organisms as fresh water.

Birds observed on the Florida Keys and the Southern End of the Mainland of Florida in 1919, by Paul Bartsch.

Dec. 28–31.—Along the coast of Florida only a few immature laughing gulls and man-o'-war birds were seen.

Jan. 1.—Entering the harbor of Key West in the afternoon, we saw a man-o'-war bird chasing a royal tern.

Jan. 2.—In a trip to the United States Bureau of Fisheries station, I saw only a number of little sparrow hawks, 8 yellow palm warblers, 2 mocking-birds, 6 man-o'-war birds, many laughing gulls, mostly immature, a few royal terns, 2 belted kingfishers, 2 Florida ground doves, 2 Ward's herons, 1 great white heron, 4 brown pelicans, and a number of turkey vultures.

Jan. 3.—Sailing for the Tortugas, a "southwester" forced us to seek shelter behind the Marquesas. Only a couple of man-o'-war birds and a few brown pelicans were seen.

Jan. 4.—In the same position, only a few brown pelicans and a couple of man-o'-war birds were listed.

Jan 5.—While carefully examining the sand beaches, etc., in order not to miss any birds that prefer particular habitat, we saw only a catbird and 4 ospreys, one pair having a nest containing two eggs in advanced incubation, 1 great white heron, 3 Ward's herons, 15 brown pelicans, 5 belted kingfishers, 11 yellow palm warblers, 4 Florida ground doves,

1 laughing gull, 5 little sparrow hawks, 1 broad-wing hawk, 14 least sandpipers, and a small flock of semi-palmated plovers.

Jan. 6.—Near the little harbor of Boca Grande Key, the following data were obtained: Several osprey's nests without eggs were examined, but only 4 adult birds were noted. The lake in the interior harbored about 100 brown pelicans. Over 100 Ward's herons were in the trees bordering the lake, many of them having nests, but up to that time there seemed to be no eggs present. We also saw a Louisiana heron and a great white heron; on the outer sand beach 6 grasshopper sparrows and 2 Florida ground doves, while in the depression inside of the sand dunes were 3 killdeer plovers, 30 semi-palmated plovers, 15 sanderlings, and a ruddy turnstone. Additional birds seen during the day were: 1 marsh hawk, 1 Florida red-shouldered hawk, 1 little sparrow hawk, 1 laughing gull, 1 green heron, 3 belted kingfishers, 1 royal tern, and 2 man-o'-war birds.

Jan. 7.—On the same beach Florida ground doves and grasshopper sparrows were again seen; also a Savanna sparrow. A trip around the island in a skiff brought us to quite a colony of yellow-crowned night herons, also a large number of Ward's and a few great white herons. On the inside is a beautiful lake, with an island in its center, and here a small flock of brown pelicans could be seen floating about, while quite a number of Ward's herons and a few great white herons, also quite a number of black- and yellow-crowned night herons and 8 Louisiana herons were present. We found 4 empty osprey nests of remarkably large size near the ground, evidently the accumulations of many years, and nearby in each instance a lesser structure up in tall dead trees. At the north end of the island we saw brown pelicans floating and the heron complex alluded to above. One dead brown pelican was found, recently stranded on the beach. Others seen this day were belted kingfisher, mocking-bird, Florida ground dove, killdeer, semipalmated plover, laughing gull, herring gull, royal tern, grasshopper sparrow, and yellow palm warbler.

Jan. 8.—We started early in the morning for the Tortugas. After passing Rebecca Light, another "southwester" overtook us and it was interesting to note that flying royal terns were all heading in one direction, which proved to be toward the islands of the Tortugas group. On coming to anchor about 5 p. m., we found red-footed boobies occupying most of the stakes in the channel; also a few brown pelicans, royal terns, herring gulls, and laughing gulls.

Jan. 9.—Early in the morning we left in the launch for Loggerhead Key. On our way we saw red-footed boobies on the harbor stakes; also a few pelicans, laughing gulls, royal terns, and some herring gulls on wing. The entire day's count yielded only 4 little sparrow hawks, 1 yellow palm warbler, 2 brown pelicans, and 4 killdeer plovers. In opening one of the laboratories we found that a chuck-will's-widow had become entrapped in the building, and its well-prepared skeleton was surrounded by a halo of feathers, a new record for Loggerhead Key.

Jan. 10.—No other birds observed.

Jan. 11 to 15.—5 species only were observed and these are: 4 little sparrow hawks, 8 brown pelicans, 4 killdeer plovers, 2 royal terns, and 1 palm warbler.

On Garden Key we observed a little sparrow hawk, and in the adjacent waters were red-footed boobies, royal terns, brown pelicans, and a few man-o'-war birds.

On Long Key, we found a couple of herring gulls, royal terns, and brown pelicans, while Bush Key was empty.

In 1917 I had left with the lighthouse keeper an alcohol tank and material for preserving birds that might strike on the lighthouse. The following 10 specimens were saved: belted kingfisher, Oct. 8, 1917; oven bird, Oct. 10, 1917; common tern, Nov. 11, 1917; belted kingfisher, Mar. 13, 1918; prairie warbler, Mar. 18, 1918; yellow-billed cuckoo, Mar. 30, 1918; myrtle warbler, Mar. 31, 1918; catbird, Apr. 26, 1918; bobolink, Nov. 1, 1918; gray-cheeked thrush, Nov. 23, 1918.

Jan. 16.—A visit to Fort Jefferson revealed a little sparrow hawk and a single yellow palm warbler. At one time during the afternoon a flock of 28 man-o'-war birds hung over the southeast corner of the fort, riding on the air upthrust by the wall of the fort.

Jan. 17.—We left for Key West aboard the *Anton Dohrn*. We saw quite a number of ospreys' nests on the west side of the Marquesas islands. Near Key West we passed small groups of laughing gulls and also of royal terns, the former resting in the water and the latter usually standing on driftwood.

Jan. 18.—During a trip from La Breza to the second Martello tower we noted the following birds: Florida ground dove, turkey buzzard, man-o'-war bird, brown pelican, laughing gull, royal tern, many yellow palm warblers, 3 scissor-tailed fly-catchers, 2 Arkansas fly-catchers, belted kingfisber, and mourning dove; also the wing and foot of a least sandpiper.

Jan. 19.—At Newfound Harbor Key we found yellow palm warblers and a parula warbler. Brown pelicans were fishing offshore and a belted kingfisher and a green heron were along the edge, while a turkey vulture flew over. We next visited the little key northeast of Newfound Harbor Key, where we had found the Louisiana herons breeding in 1918. Brown pelicans and man-o'-war birds were using this island as a roosting-place, and we also saw a great white heron and a belted kingfisher. No less than 6 great white herons could be seen standing in the shallow waters of the neighboring keys.

Jan. 20.—At Bahia Honda Key we saw the following: brown pelican, turkey buzzard, little sparrow hawk, yellow palm warbler, Florida ground dove, Bahama red-winged blackbirds, ruby-throated hummer, killdeer, and a belted kingfisher. On Duck Key we found 2 great white herons, a brown pelican, a yellow palm warbler, one Savanna sparrow, and 2 grasshopper sparrows.

Jan. 21.—We saw a red-throated loon off Indian Key, and on the key itself common terns, royal terns, a broad-winged hawk, 2 little sparrow hawks, catbird, a pair of mocking-birds, Florida cardinal, Florida yellow-throat, 3 spotted sandpipers, and a laughing gull. At Tea Table Key, nearby, the Florida cardinal and mocking-bird were present.

Jan 22.—At Porgee Key the following were noted: man-o'-war bird, brown pelican, herring gull, laughing gull, royal tern, common tern, Louisiana heron, a small flock of American egrets, a flock of more than 100 Florida double-crested cormorants, belted kingfisher, mocking-bird, and Florida cardinal. In the afternoon at Ragged Keys and on the first key north of Sands Key we saw a yellow-crowned night heron and a belted kingfisher.

On our trip through Bay Biscayne to Miami a large flock of Florida cormorants was noted; likewise, brown pelicans, laughing gulls, herring gull, ring-billed gull, royal tern, and common tern.

I revisited Florida later in the season. With the use of the *Darwin*, a shallow-draft launch, we cruised along the mainland of the lower peninsula, through Key Biscayne Bay, Card Sound, Little Card Sound, and Barnes Sound, stopping at every likely-looking sand-spit. We then returned by way of the eastern edge of these bays, following the inside of the outer keys back to Miami, stopping at intervals to explore the keys. An anchorage was made for the *Anton Dohrn* at Indian Key, and from here we again set out with the *Darwin* across the extensive flats of Florida Bay for Cape Sable. We explored the region about Flamingo City and east of Flamingo City and made a trip inland to Coot Bay.

May 2.—At Miami we saw the following about the streets of the town: mocking-bird, night hawk, Florida ground dove and red-bellied woodpecker; on Virginia Key, man-o'-war bird, royal tern, Florida cormorant, Florida cardinal, Key West vireo, spotted sandpiper, ruddy turnstone, and one redstart were recorded.

May 3.—In leaving Miami and passing out of the river, we saw a group of purple martins flying about; also some royal terns and a couple of man-o'-war birds. At Elliott Beach we noted a Florida cardinal and a Florida yellow-throat. At Key Biscayne Bay, on the outer beach, we found a flock of pectoral sandpipers and a pair of semi-palmated plovers. About 4 p. m. we reached the drainage ditch leading to Homestead. We visited several hammocks near the canal and obtained the following list: 1 black-crowned night heron, 6 spotted sandpipers, 1 Florida ground dove, 7 Florida meadow larks, 3 kingbirds, 2 mocking-birds, 3 turkey buzzards, 9 Bahama red-winged blackbirds, and 1 Florida crow.

We next headed for the Arsenicker Keys and found on the one off Mangrove Key a breeding colony of Louisiana herons with probably 100 nests; there also seemed to be some breeding Florida cormorants on this island; also a brown pelican and a man-o'-war bird roost, containing over 100 brown pelicans, chiefly young birds, and about 50 man-o'-war birds. The shallows which stretch for a considerable distance from the shore off this key were occupied by large numbers of fishing brown pelicans and a single Ward's heron. At twilight a pair of great white herons settled down on the flats and quite a number of brown pelicans spent the night nearby.

May 4.—At dawn many brown pelicans were present on the flats about us and a pair of ospreys were fishing in the shallows. At the northern end of the mainland, in Card Sound, we saw a pair of red-bellied woodpeckers and from here a pair of turkey buzzards and some man-o'-war birds could be seen on wing, while royal terns were resting on the shallows offshore, which were also tenanted by a great white heron and a pair of Ward's herons. About one-third of the way down the sound we saw a broad-winged hawk. At Card Point were Bahama red-winged blackbirds and boat-tailed grackles; a few Florida cormorants were seen in the sound. The stakes marking the entrance to Barnes Sound supported about two dozen Florida cormorants, and some royal terns were flying about. On Main Key we saw a prairie warbler and two Florida cardinals. About halfway between

Flat Point and Bay Point we met the following: bald eagle, white-eyed towhee, Key West vireo, Cape May warbler, southern parula warbler, black-poll warbler, and kingbird. On a line of keys which make out into the bay from the point of Cross Key, we found about 200 man-o'-war birds and probably 500 pairs of Louisiana herons; also a pair of anhingas breeding, the nest containing two young just hatched and two eggs about ready to emit their chicks. At Peacon place, on Key Largo, we saw redstarts, Florida ground doves, Florida cardinals, and Cape May warblers.

May 5.—Our first stop was at Scott's place, on Key Largo, about half a mile below Pumpkin Key, where we found a Florida red-shouldered hawk nesting, gray kingbird, Key West vireo, redstarts, red-bellied woodpecker and Florida cardinals.

Our next stop on Key Largo was about halfway between Pumpkin Key and Angel Fish Creek. Here we found Florida cardinals, yellow-bellied woodpeckers, and Key West vireos.

Palo Alto Key was next visited, and we noted a Florida crow, Key West vireo, Florida cardinal, and red-bellied woodpecker.

May 6.—At dawn we stopped at Totten's Key, where we found a Florida screech owl with a brood of young in a low cavity; also, Key West vireos, Florida cardinals, an ovenbird, gray kingbirds, and a Florida crow. At Porgee Key we saw a redstart, Key West vireo, and Florida cardinal. On Old Roads Key we saw Florida cardinals and Key West vireos. At Sands Key we found prairie warblers, Key West vireos, and Florida cardinals.

May 7.—We left Miami with the *Anton Dohrn* and came to anchor off Rodriguez. During our trip through Hawk Channel we saw only a few man-o'-war birds.

May 8.—We steamed for Indian Key about daybreak and came to anchor off that key at 10 a. m. At 11 a. m. we set out for Cape Sable in the *Darwin*. Some turkey vultures were observed and a couple of least terns. The flat between the viaduct and Sands Key, off Cape Sable, showed only an occasional Florida cormorant, man-o'-war bird, or laughing gull. On the extensive flats lying off this island two great white herons were visible, and about 20 brown pelicans, quite a number of Florida cormorants, and some man-o'-war birds, the latter on wing. On the key itself we found prairie warblers, Florida yellow-throats, black-poll warblers, a pair of Florida great crested fly-catchers, and a grasshopper sparrow. I was told that a pair of flamingoes had been shot on the flat this spring and that in the days gone by it was not uncommon for flamingoes to come over onto the Florida flats from the Bahamas in the morning and to return to the Bahamas at night, after a day's feeding in the shallows. Opposite Flamingo are several keys which are used as roosting-places by white ibises and various species of herons.

May 9.—We were on shore shortly after daylight. Florida meadow larks and Bahama red-winged blackbirds are the chief birds, although we also flushed several grasshopper sparrows and I saw 6 swallow-tailed kites in the air at one time, a larger number than I have previously seen. About 10 a. m. we set out for Coot Bay, which contained a few scattered waterfowl. The following is a list of birds seen between Flamingo and Coot Bay: American egret, snowy egret, Louisiana heron, Florida cormorant, Florida cardinal, gray kingbird, red-bellied woodpecker, Florida crow, Florida ground dove, Key West vireo, everglade kite, Bahama red-winged blackbird, ruby-throated hummer, spotted sandpiper, boat-tailed grackles, grasshopper sparrows, Florida pileated woodpecker, Florida red-shouldered hawk, bald eagle, osprey, great white heron, brown pelican, white ibis, Florida yellow-throat, and swallow-tailed kite. We also saw two nests of the latter bird, both of which we examined and found empty. They are rather different from the usual raptor's nest, being more compact and much more elevated and inverted conic in outline than any other hawk nest that I have examined.

May 10.—We left Flamingo City shortly after daylight on May 10. Our first stop was at the East Cape Club House. The birds seen were Florida crow, turkey buzzard, brown pelican, Bahama red-winged blackbirds, Florida meadow lark, Ward's heron, and American egret. We next rounded East Cape, and here again put ashore. Fringing the shore between East Cape and Middle Cape, we saw the red-bellied woodpecker. Key West vireos could be heard everywhere, and this bird and the Florida cardinal appeared to be of about equal abundance. Florida crows were also quite common and occasionally a Florida ground dove was flushed, and in one instance we found a nest containing two young. Along the shore an occasional spotted sandpiper would keep pace with our advance for some distance. Off Sands Key we found a remarkable flight of Florida yellow-throats. There were literally thousands of these birds of both sexes. I have never before seen so many individuals of a species gathered together in such a compact space. Mixed in with these we found a few black-poll warblers, prairie warblers, and redstarts; also a few Key West vireos and a pair of gray kingbirds, while offshore a couple of royal terns and laughing gulls, some man-o'-war

birds and brown pelicans, a great white heron, a Louisiana heron, and some Florida cormorants were resting on the water, and a flock of white-bellied swallows were skimming over the land and the sea.

May 11.—We arrived at Newfound Harbor Key at noon. At 1 p. m. we visited the key which has the Louisiana heron rookery on it. It is occupied by the usual group of man-o'-war birds, a small flock of brown pelicans, mostly young, many of them fishing, at which art they were still quite inexperienced. The Louisiana herons were breeding here in great numbers this year. There was also a huge Ward's heron nest in the large tree standing on the high ground in the center of the island. This nest contained an almost fledged young bird. A second visit to this key revealed a young bald eagle seated on a dead limb. The seventh key southwest of Big Pine Key is a mere clump of black mangrove bushes with a sandspit. This sandspit contained as many as 50 least terns. They were not breeding at this time, although their actions would indicate that they intended to use this key for a nesting-ground. In the tall bushes at the opposite end of the island we found a huge nest of the great white heron containing an almost fledged young, which we subjected to considerable photographing, and which eventually we carried to Key West and sent by parcel post to the Zoological Garden at Washington, where it has grown into an exceedingly fine specimen of this magnificent species. Flying over this little key we also found Bahama red-winged blackbirds, Florida yellow-throats, prairie warblers, and man-o'-war birds.

May 12.—We made a list of the following birds: On the first key southwest of Big Pine Key we saw a flock of about 25 least sandpipers, 6 black-bellied plovers, and about 25 semi-palmated plovers. In addition to these, we listed Louisiana herons, redstarts, boat-tailed grackle, Florida yellow-throats, Florida cardinals, and Key West vireos. On the second key southwest of Big Pine Key we saw redstarts, a Cape May warbler, a red-eyed vireo, a pair of Key West vireos, and a great white heron. The third key southwest of Big Pine Key showed Florida yellow-throats, turkey vulture, Key West vireo, Florida cardinal, gray kingbird, yellow-billed cuckoo, catbird, boat-tailed grackle, black-and-white creeping warbler, red-bellied woodpecker, and a redstart. On the fifth key southwest of Big Pine Key we saw a laughing gull, Florida yellow-throats, brown pelicans, and a gray kingbird. The sixth key southwest of Big Pine Key was again visited and I photographed a young Ward's heron in the nest. The young bald eagle was again seen on the same high dead limb in the center of the island; man-o'-war birds and brown pelicans were abundant as usual, and I succeeded in shooting a clapper rail which was needed to positively determine the species. This rail proves to be, according to Dr. Oberholser, a new subspecies which he has named Mangrove rail. We also found Florida yellow-throats, a gray kingbird, and boat-tailed grackles. The seventh key southwest of Big Pine Key furnished the following: great white heron, laughing gulls, Bahama red-winged blackbirds, least terns, gray kingbirds, Florida yellow-throat, and a Mangrove rail. The eighth and last key southwest showed only 2 Louisiana herons.

May 13.—In the afternoon we paid a visit to the United States Bureau of Fisheries Station on Key West, but observed only man-o'-war birds, green heron, and gray kingbird.

May 14.—On Stock Island the following list was obtained: Ward's heron, Louisiana heron, green heron, least tern, royal tern, brown pelican, man-o'-war bird, and Bahama red-winged blackbirds.

May 15.—On the way to the Tortugas very few birds were seen between Key West and our islands. Our list comprises man-o'-war birds, royal terns, and an occasional blue-faced booby. Passing Bird Key showed that there were few birds on wing. On Loggerhead Key the following were seen: sharp-shinned hawk, little sparrow hawk, man-o'-war bird, least tern, yellow warbler, gray kingbird.

May 16.—At Loggerhead Key I noted the following: 1 Bahama red-winged blackbird, 2 gray kingbirds, 1 yellow palm warbler, 1 female redstart, and 1 little sparrow hawk. At Bird Key, the same day, I found the usual dense population of sooty and noddy terns, but the sooties were mostly nesting on the ground on bits of sticks pulled together from the dead rubbish. I shot a blue-faced booby with a very curiously mottled plumage. On our return to Loggerhead Key I saw a little blue heron, man-o'-war birds, and a small flock of barn swallows.

May 17.—We visited Fort Jefferson on Garden Key and noted the following: Florida yellow-throat, olive-backed thrush, black-poll warbler, yellow palm warbler, prairie warbler, Cape May warbler, ovenbird, catbird, redstart, yellow-billed cuckoo, black-billed cuckoo, red-eyed vireo; while flying about the fort could be seen man-o'-war birds, royal terns, sooty and noddy terns, and a few least terns. On Bush Key the following were seen: man-

o'-war birds, Florida yellow-throat, laughing gull, royal terns, least tern, Cabot's tern, ruddy turnstone, and oyster-catcher. On Long Key the least tern, Cabot's tern, royal tern, laughing gull, man-o'-war birds, brown pelicans, Ward's heron, Florida yellow-throat, ruddy turnstone, and oyster-catcher were observed.

On another trip through Loggerhead Key I found two bunches of feathers, one belonging to a summer tanager and the other a yellow-billed cuckoo; at sunset we saw an osprey and a duck hawk, the latter evidently intending to roost for the night on one of the dead flowering stalks of a clump of agaves. This is the first time that I have seen this bird in this region. The following had struck on the lighthouse since my last visit to this island and had been preserved in the alcohol tank: blue-winged teal, male, Feb. 26, 1919; prairie warbler, Mar. 19, 1919; Wilson's snipe, Mar. 26, 1919; Wilson's Snipe, two prairie warblers, and yellow palm warbler, Mar. 27, 1819; oven bird and Florida yellow-throat, black-throated blue warbler, and prairie warbler, May 2, 1919.

May 18.—I saw the following birds on Long Key: Ward's heron, laughing gull, royal tern, man-o'-war birds, and brown pelican. I again saw the duck hawk which passed me at less than 35 feet distance several times today, also an osprey on Loggerhead Key. We have come to the conclusion that a little sparrow hawk is responsible for the erratic distribution of cerions in the vicinity.

May 19.—Few birds were seen between the Tortugas and Key West. The list included some brown pelicans, man-o'-war birds, royal terns, an occasional blue-faced booby, and laughing gull.

Scientific Equivalents for the Common Names of Birds Used in the Preceding List.

Red-throated loon = Gavia stellata.
Herring gull = Larus argentatus.
Ring-billed gull = Larus delawarensis
Laughing gull = Larus atricilla megalopterus.
Royal tern = Thalasseus maximus.
Cabot's tern = Thalasseus sandvicensis acuflavidus.
Common tern = Sterna hirundo.
Least tern = Sternula antillarum antillarum.
Sooty tern = Sterna fuscata.
Noddy tern = Anous stolidus stolidus.
Blue-faced booby = Sula cyanops.
Red-footed booby = Sula sula.
Anhinga = Anhinga anhinga.
Florida cormorant = Phalacrocorax auritus floridanus
Brown pelican = Pelecanus occidentalis occidentalis.
Man-o'-war bird = Fregata magnificens rothschildi.
Blue-winged teal = Querquedula discors.
Flamingo = Phœnicopterus ruber.
White ibis = Guara alba.
Great white heron = Ardea occidentalis.
Ward's heron = Ardea herodias wardi.
American egret = Herodias egretta.
Snowy egret = Egretta candidissima candidissima.
Louisiana heron = Hydranassa tricolor ruficollis.
Little blue heron = Florida cærulea cærulea.
Green heron = Butorides virescens virescens.
Black-crowned night heron = Nycticorax nycticorax nævius.
Yellow-crowned night heron = Nyctanassa violacea.
Mangrove rail = Rallus longirostris helius.
Wilson's snipe = Gallinago gallinago delicata.
Pectoral sandpiper = Pisobia maculata.
Least sandpiper = Pisobia minutilla.
Sanderling = Calidris alba.
Spotted sandpiper = Actitis macularia.
Black-bellied plover = Squatarola squatarola cynosuræ.
Killdeer plover = Oxyechus vociferus vociferus.
Semipalmated plover = Charadrius semipalmatus.
Ruddy turnstone = Arenaria interpres morinella.
Oyster-catcher = Hæmatopus palliatus palliatus.
Mourning dove = Zenaidura macroura carolinensis.
Ground dove = Chæmepelia passerina passerina.
Turkey vulture = Cathartes aura septentrionalis.
Swallow-tailed kite = Elanoides forficatus forficatus.
Everglade kite = Rostrhamus sociabilis.
Marsh hawk = Circus cyaneus hudsonius.
Sharp-shinned hawk = Accipiter velox.
Florida red-shouldered hawk = Buteo lineatus alleni.
Broad-winged hawk = Buteo platypterus platypterus.
Bald eagle = Haliaetus leucocephalus leucocephalus.
Duck hawk = Rhynchodon peregrinus anatum.
Little sparrow hawk = Cerchnies sparveria paula.
Osprey = Pandion haliaetus carolinensis.
Florida screech owl = Otus asio asio.
Yellow-billed cuckoo = Coccyzus americanus americanus
Black-billed cuckoo = Coccyzus erythropthalmus.
Belted kingfisher = Streptoceryle alcyon alcyon.
Yellow-bellied sapsucker = Sphyrapicus varius varius.
Florida pileated woodpecker = Phlœotomus pileatus floridanus.
Red-bellied woodpecker = Centurus carolinus.
Chuck-will's widow = Antrostomus carolinensis.
Nighthawk = Chordeiles minor minor.
Ruby-throated hummingbird = Archilochus colubris.
Scissor-tailed flycatcher = Muscivora forficata.
Kingbird = Tyrannus tyrannus.
Gray kingbird = Tyrannus dominicensis dominicensis.
Arkansas fly-catcher = Tyrannus verticalis.
Florida great crested fly-catcher = Myiarchus crinitus residuus.
Florida crow = Corvus brachyrhynchos pascuus.
Bahama red-winged blackbird = Agelaius phœniceus bryanti.
Florida meadow lark = Sturnella magna argutula.
Boat-tailed grackle = Megaquiscalus major major.
Savannah sparrow = Passerculus sandwichensis savanna.
Grasshopper sparrow = Ammodramus savannarum australis.
White-eyed towhee = Pipilo erythrophthalmus alleni.
Florida cardinal = Cardinalis cardinalis floridanus.
Summer tanager = Piranga rubra rubra.
Purple martin = Progne subis subis.
White-bellied swallow = Iridoprocne bicolor.
Red-eyed vireo = Vireosylva olivacea.
Key West vireo = Vireo griseus maynardi.
Black-and-white warbler = Mniotilta varia.
Parula warbler = Compsothlypis americana americana.
Cape May warbler = Dendroica tigrina.
Yellow warbler = Dendroica æstiva æstiva.
Black-throated blue warbler = Dendroica cærulescens cærulescens.
Myrtle warbler = Dendroica coronata coronata.
Black-poll warbler = Dendroica striata.
Palm warbler = Dendroica palmarum palmarum.
Yellow palm warbler = Dendroica palmarum hypochrysea.
Prairie warbler = Dendroica discolor.
Oven bird = Seiurus aurocapillus aurocapillus.
Florida yellow-throat = Geothlypis trichas ignota.
Redstart = Setophaga ruticilla.
Mocking-bird = Mimus polyglottos polyglottos.
Catbird = Dumetella carolinensis.
Grey-cheeked thrush = Hylocichla minima aliciæ.
Olive-backed thrush = Hylocichla ustulata swainsoni

DEPARTMENT OF MERIDIAN ASTROMETRY.*

BENJAMIN BOSS, DIRECTOR.

The activities of the Department during the last year may be grouped under four general heads: investigations of stellar motions, reduction of observations, preparations for the General Catalogue, and preparations for future work.

INVESTIGATIONS OF STELLAR MOTIONS.

PARALLAXES.

In order .to determine as accurately as possible the real space motions of the stars it has been found necessary to reconcile as well as possible the various series of stellar parallax observations, utilizing all available material. A preliminary system was already completed when a large number of unpublished parallaxes were very generously offered by Professors Schlesinger, Mitchell, Frost, and Miller, and it became necessary to revise the system. While the last approximation to definitive results has not been completed, several conclusions will not be materially altered.

The trigonometrical parallaxes obtained by the photographic process are in general of a high degree of excellence; and their relative weights are very approximately represented by the probable errors assigned by the authors to their observations. While systematic corrections depending upon progression in right-ascension have been derived, in addition to constant corrections, they are very small and might easily vanish with the accumulation of data, though the effect appears to be well marked in some instances.

The mean probable error of the parallaxes derived according to Adams's method are of an order comparable to those determined by the trigonometrical method, but the probable error varies with the size of the parallax. As Adams's system is founded upon trigonometrical parallaxes, certain corrections to it are to be expected with the accumulation of results. Thus, it appears that for very small parallaxes a considerable minus correction must be applied. This may be partly accounted for if Adams used small positive parallaxes in fixing this part of the curve, more or less neglecting the minus parallaxes. After the application of all the corrections, Adams's results were treated for effect depending upon spectral classification. It was anticipated that a decided dispersion effect would be found, but curiously enough an approximately linear correction developed, positive for M-class dwarfs. It was also surprising to find that the probable error of a parallax derived from a single plate was not improved by the employment of several plates.

*Address: Dudley Observatory, Albany, N. Y.

The system of parallaxes which is being formed is in no way intended to be taken too seriously, as it is liable to undergo considerable changes with the accumulation of data, but it is primarily intended to furnish a means for deriving the real motions of the stars as approximately as may be at the present time.

THE VERTEX OF STELLAR MOTIONS.

Mr. Raymond prepared for publication an uncompleted paper by Professor Lewis Boss on the vertex of stellar motions. This paper, though practically completed before Professor Boss's death, was never published. It offers a simple approximate solution of this complicated problem by a method partly graphical.

The position of the vertex of preferential motion was found to be $170^\circ.7, -2^\circ.5$ in galactic coordinates, or $6^h\ 15^m.2$, $+7^\circ\ 0'$ in equatorial coordinates, in very good agreement with the results obtained by other investigators. The ratio of the three unequal axes of the velocity figure proved to be 2.2 : 1.3 : 1, showing the distinct flattening of the velocity figure in the direction perpendicular to the galactic plane.

VARIATIONS OF SPECTRAL TYPE IN CEPHEID VARIABLES.

The work of Dr. Albrecht on variations of spectral type in Cepheid variables has been continued and brought to completion for the stars l Carinæ and η Aquilæ. In the definitive results the former of the two stars was found to vary from F8 to G9; the latter from F6 to G6. These results, which are based upon the general spectrum, are apparently directly opposed to the recent results of Adams and Joy, who found that the variations of type in Cepheids are confined to the hydrogen spectrum and that the general spectrum does not share in these changes. Accordingly, Dr. Albrecht's data were rediscussed with special reference to their possible explanation by the two following effects in the general spectrum, also referred to by Adams and Joy: (1) a general slight widening of the spectral lines at minimum, and (2) an increase in the intensity of the so-called "enhanced" lines at maximum. A detailed examination shows that nearly all the shifts in wave-length in these Cepheids are satisfactorily explained by a strengthening or a weakening of the same components of the lines (blends) as in the stellar spectra from the "earlier" to the "later" types, rather than by the widening of the lines at minimum or a strengthening of the enhanced lines at maximum, or both.

Thus, for the present at least, it seems impossible to harmonize Dr. Albrecht's results and those of Adams and Joy. It should be noted that Dr. Albrecht's results would bring into accord for Cepheids simultaneous changes of visual light, of photographic light, of radial velocity, of type based on the general spectrum, of type based on the hydrogen spectrum, and of color-index both observed photographically

and computed from the changes of type. On the contrary, if the general spectrum does not share in the changes of type shown by the hydrogen spectrum, according to the results of Adams and Joy, then the changes of color-index computed from the general spectrum are practically zero, constituting an apparent outstanding discordance.

A tabulation for a number of Cepheids also showed: (*a*) a progressive trend of types with increasing length of period (known before), the effect being, however, very much more pronounced for short than for longer periods, and (*b*) the apparently complete lack of a relation between the range through which the type varies and the period. The type range in the 22 Cepheids listed averages one type-interval (as F to G), with only moderate deviations from the mean.

Inasmuch as the surface conditions on Cepheids, *i.e.*, in the comparatively shallow layer in which all of the light that reaches us originates, are undergoing constant and apparently violent changes, it seems probable that a considerable overlapping of the distinguishing characteristics of types takes place. With good modern instrumental equipment, applied especially to the brighter Cepheids, it should be possible to determine approximately the extent to which Cepheid spectra deviate from pure stellar types.

REDUCTION OF OBSERVATIONS.

The observations of the secondary observers made at San Luis have been investigated for systematic errors, and their relation to the results of the fundamental observers ascertained. For the night observations of the five observers the latitude (omitting $-30° 17'$) and the refraction coefficients are respectively as follows: Roy 45″.54, 0.9926; Sanford 45″.48, 0.9950; Tucker 45″.78, 0.9916; Varnum 45″.51, 0.9942; and Zimmer 45″.49, 0.9936. It may be remarked, as has been suggested elsewhere, that the discrepancy in the mean latitude may be entirely due to personalities in determining the nadir; or the zenith correction should be applied otherwise than symmetrically north and south.

The collation of results is well advanced and the computation of precession for the catalogue has been started.

The first steps have been taken in the reductions of all the Albany observations. The observations made during the last year of observing have been brought to the same stage as the previous Albany series. The corrections for south minus north and eye and ear minus chronograph were computed and applied. The first reductions of double transits of circumpolar stars were made and preliminary places derived for the 19 primary azimuth stars. Using these places, azimuths were computed and plotted and curves drawn to represent them for those series of the Albany observations where there were 12 and 24 hour groups of clock stars. These are furnishing the material for the first investigation of the systematic correction in right-ascension depending upon right-ascension now in progress.

From the preliminary clock corrections already obtained, it would appear that the Riefler clocks have been less subject to a diurnal term at Albany than at San Luis.

PREPARATIONS FOR THE GENERAL CATALOGUE.

Further progress has been made on the general catalogue. The observations taken from catalogues received within recent years are being entered upon the card catalogue. The systematic relations of the following catalogues to the standard system have been wholly or in part determined:

1.	Moscow	1860	0° to +4°.
2.	Berlin	1865	Largely zodiacal.
3.	Warsaw	1880	−2° to −7°.
4.	Pulkova	1885	Observations of Romberg.
5.	Cincinnati	1895	Largely proper-motion stars.
6.	Abbadia	1900	+5° to −3°. Astrographic Standards.
7.	Abbadia	1900	+16° to +24°. Astrographic.
8.	Abbadia	1900	−3° to −9°. Astrographic.
9.	Abbadia	1900	Fundamental for three preceding.
10.	Brussels	1900	+21° and 22°.
11.	Cape	1900	N of −34°. Largely zodiacal.
12.	Cordoba Gen. Cat.	1900	With miscellaneous stars, largely −15° to −35°.
13.	Cordoba Zone	1900	−22° to −27°.
14.	Christiania	1900	+65° to +70°.
15.	Dublin	1900	Various.
16.	Edinburg	1900	Zodiacal.
17.	Greenwich	1900	General, zodiacal, and astrographic standards.
18.	Hamburg	1900	+80° to 81°.
19.	Harvard Zone	1900	−10° to −14°.
20.	Lick, Vol. X	1900	Zodiacal.
21.	Munich	1900	Largely +45° to +60°.
22.	Nice	1900	Struve and other stars.
23.	Odessa	1900	Fundamental.
24.	Perth	1900	−31° to −42°.
25.	Pulkova	1900	Fundamental.
26.	Radcliffe	1900	0 to +5°. Zodiacal and various.
27.	Washington Zone	1900	−14° to −18°.
28.	Berlin	1905	Various.
29.	Berlin C	1905	+70° to +75°.
30.	Perth	1905	Fundamental for Perth 1900.
31.	La Plata	1925	−52° to −57°.

Several other catalogues may be useful at a later stage, but have been laid aside for the present because of lack of stars in common with the general catalogue, or because they contain few or no fundamental stars from which systematic corrections can be derived.

It is now possible to compute refined positions and proper-motions where they are immediately needed. Such positions and proper-motions have been furnished to Dr. Heber D. Curtis in connection with his studies on the Einstein effects.

PREPARATIONS FOR FUTURE WORK.

Plans for the future operations of the Department are gradually progressing. As a first step a survey is being taken of the stars mainly between 8.0 and 9.0 magnitudes to determine the selection of an

observing list for the meridian circle which shall include one star per square degree. It is desirable to select stars, as far as possible, with known spectral type and with a sufficient number of observations taken in the past to insure the determination of a very approximate proper-motion; but it is also desirable to select stars from the lists of the Carte du Ciel. Those stars which are contained in the General Catalogue are given the preference. They have been plotted to facilitate making a choice. Likewise the stars contained in the new Draper Catalogue are plotted as far as published. In some regions where there are gaps it will be necessary to step outside the adopted limits of magnitude in order to secure the desired symmetrical distribution, but the percentage of such cases to the total number of stars involved is very small.

Preparations have been completed for an expedition to aid in the selection of an observing-site, as the climate at Albany is not favorable for such a project as is contemplated. A 5-inch photographic doublet lens of 13 feet focal length was kindly loaned by the Mount Wilson Observatory, and has been mounted on a telescope specially designed to meet the requirements of transportation. It is intended to test the relative conditions of seeing at various stations by comparison of star-trails taken at different altitudes. The preliminary tests at Albany were entirely satisfactory.

A survey of the U. S. Weather Bureau reports for the entire United States leads to the investigation of two regions—the south Atlantic States and Arizona. While the western conditions are in general more favorable than those in the East, there is a large diurnal range in temperature to be found in any desert region, as well as a large annual range. The distribution of clear weather appears to be fairly uniform in the Southeastern States, and it is amply sufficient for the requirements, while the diurnal range in temperature is favorable to good seeing.

STAFF.

The Director was absent for a portion of the year in attendance upon the meeting of the International Research Council at Brussels. He has continued his investigation of stellar parallaxes and has devoted considerable time to the problems arising out of the proposed future work of the Department. Dr. Sebastian Albrecht has continued his investigation of standards of wave-length, and has also been occupied with the spectral variation in Cepheids. Some time has also been devoted to the new project. Mr. Sherwood B. Grant has been absent in the naval service as marine engineer. Mr. Heroy Jenkins has been largely occupied in deriving the systematic corrections to catalogues received during the last few years. Mr. Harry Raymond has been occupied with many departments of the work. Mr. Arthur J. Roy, as formerly, has supervised the reduction and discussion of the observa-

tions and has been in charge of the Department during the absence of the Director. Mr. William B. Varnum has supervised and discussed many of the results. Dr. Ralph E. Wilson has been engaged on problems connected with the projected work.

A great deal of credit is due the computing staff, which has conscientiously performed the long and voluminous computations upon the work in hand. It has consisted of Mrs. Lillian F. Blanchard, Miss Grace I. Buffum, Mrs. Livia C. Clark, Miss Mabel I. Doran, Miss Alice M. Fuller (who is also secretary of the Department), Mrs. Mary B. James, Miss Isabella Lange, Miss Marie Lange, Miss Frances L. MacNeill, and Miss Helen M. MacNeill.

The resignation of Mrs. Mary B. James took place in June 1919.

MOUNT WILSON OBSERVATORY.*

GEORGE E. HALE, DIRECTOR.

The fortunate conclusion of the war, followed by the successful tests of the 100-inch Hooker telescope described in this report, mark a distinct epoch in the progress of the Observatory. In returning from war service to our customary field of research,[1] and in undertaking systematic observations with this exceptional instrument, we are called upon to survey all aspects of the Observatory's work and to prepare a program utilizing in the most effective possible manner the entire instrumental equipment at our disposal. The temptation to embark upon widely scattered investigations, each of great individual promise, but bearing little relationship to our general scheme of research, must be resisted. But this measure of restraint must not involve undue sacrifice of promising ideas or projects suggested by members of the staff or of unique instrumental possibilities. Again, we must steer between the dangers of the atrophy that may result from fixed procedure and endless routine, and the losses inevitable in an unstable and shifting policy. To appreciate the problem, and to aid in its solution, we must consider the leading features of the work already accomplished, evaluate the factors which have determined its present trend, and discern the larger possibilities of our staff and equipment in the light of recent developments in astronomy and physics.

The purpose of the Observatory, as defined at the time of its inception, was to undertake a general investigation of stellar evolution, laying special emphasis upon the study of the sun, considered as a typical star; physical researches on stars and nebulæ; and the interpretation of solar and stellar phenomena by laboratory experiments. It was recognized that the development of new instruments and methods afforded the most promising means of progress, and well-equipped machine and optical shops were provided with this end in view. The determination of stellar positions, parallaxes, and motions, and the study of other problems relating to the structure of the sidereal universe, were not regarded as primary objects in the plan, which had as its central purpose the elucidation of the life-history of a star. While it was obvious that questions of grouping, distance, and velocity are in many cases closely related to those of physical development, it was hoped that the necessary data of this nature would be forthcoming from other sources, leaving us free to concentrate upon the evolutional problem.

The progress of research, the enlarged possibilities of our instrumental equipment, and the advantages we have enjoyed from close

---

*Situated on Mount Wilson, California. Address, Pasadena, California.

[1] The war services of the Observatory have been made the subject of a special report to the President of the Carnegie Institution.

association with Professor Kapteyn, have led to a material modification of our original view. The independent and striking discovery by Campbell and Kapteyn of an important relationship between stellar speed and spectral type; the demonstration by Hertzsprung and Russell of the existence of giant and dwarf stars; the successful application of the 60-inch reflector by van Maanen to the measurement of minute parallaxes of stars and nebulæ; the important developments of Shapley's investigation of globular star-clusters; the possibilities of research resulting from Seares's studies in stellar photometry; and the remarkable means of attack developed by Adams through the method of spectroscopic parallaxes, have naturally and inevitably led to a very considerable extension of our original program. Indeed, the success of these and other investigations, and the importance of profiting by them, have resulted in a seeming reduction of emphasis on the more purely physical aspects of our attack. This is apparent rather than real, however, as the new advances will actually permit us to carry this attack well beyond some of its original objectives. Especially is this true at the present time, when the recent commissioning of the Hooker telescope and the forthcoming extension of our laboratory facilities are affording better means of utilizing such enlarged opportunities.

The investigations in solar physics, which formerly held the chief place in our research program, have also developed along unexpected lines. We did not foresee at the outset that solar magnetic phenomena would one day become a subject of our inquiry, demanding special instrumental facilities and throwing light on the complex question of the nature of sun-spots and other solar problems of long standing. It is obvious that these researches, together with those on the solar rotation and the motions of the solar atmosphere, so admirably developed by Adams and St. John, must be carried to their logical conclusion, and utilized, in the fullest possible degree, for the interpretation of stellar and nebular phenomena.

The discovery of solar magnetism, like many other Mount Wilson results, was the direct outcome of a long series of instrumental developments. At their beginning in 1890, the most powerful solar spectrograph applied to the study of sun-spots was an instrument of 42.5 inches focal length, attached to a 12-inch equatorial refractor and giving a solar image 2 inches in diameter. For many visual purposes such a combination is excellent, but it is poorly adapted for photography. A much larger solar image and a spectrograph of much greater linear dispersion are essential. In fact, the spectrograph must be made the prime element in the combination, and the telescope so designed as to serve as a necessary auxiliary. Thus, through the successive steps embodied in the horizontal Snow telescope, with its 18-foot spectrograph, and the 60-foot vertical tower telescope, with its 30-foot

spectrograph, we were led to the construction of the 150-foot tower-telescope, giving a 16.5-inch solar image, held at a fixed position within a laboratory, beneath which a vertical spectrograph of 75 feet focal length, of massive construction and extending deep into the earth, enjoys the stability and constancy of temperature required for the most exacting work. The great gain in linear dispersion thus afforded was essential for the detection and measurement of the minute line-displacements which reveal the general magnetic field of the sun.

For the moment, perhaps, the phenomena of solar magnetism, intense and fluctuating in the electric vortices of sun-spots, weaker but more constant for the sun as a whole, may throw no special light on stellar problems. But in the long run every advance in our knowledge of the sun is likely to find application in the study of other stars. The principle of initiating many stellar researches from suggestions afforded by solar investigations, and of preparing an observing program which intimately unites both of these classes of work with laboratory studies, is undoubtedly sound, and should continue to form the basis of our procedure. It is well illustrated by the development of the method of spectroscopic parallaxes, in which the absolute magnitude, and hence the distance of a star, is accurately determined from estimates of the relative intensities of certain lines in stellar spectra. Our attention was first directed toward lines of this character in 1906, when we inferred that the weakening of some lines in the spectra of sun-spots and the strengthening of others was the result of reduced temperature of the spot vapors. This hypothesis was tested by laboratory experiments and found to be verified. Subsequently, Adams, who had thus become familiar with these lines and their variability, naturally studied them extensively, with the assistance of Kohlschütter, in the spectra of other stars. In this way the dependence of their relative intensities on the absolute magnitude was discovered, thus yielding the powerful method of spectroscopic parallaxes. This method, giving the absolute magnitude as well as the distance of every star (excepting those of the earliest type) whose spectrum is photographed, is no less important from the evolutional than from the structural point of view.

Another direct outgrowth of our work on sun-spot spectra is a study of the spectra of red stars, where the chemistry of these coolest regions of the sun is partially duplicated. The combination of titanium and oxygen and the significant changes of line intensity already observed in both instances, and also in the electric furnace at reduced temperatures, are indications of what may be expected to result from an attack on the spectra of the red stars with more powerful instrumental means.

Here we may recall the steps already taken to render such an attack possible. Two requirements are to be met: We must have sufficiently

bright stellar images, together with the means of photographing their spectra under high dispersion. Experiments made by Adams with the 60-inch reflector, which was designed with this object in view, gave excellent large-scale spectra of some of the brightest stars. The ground was thus prepared for further work, with higher dispersion, which will be done with the 100-inch telescope as soon as the powerful spectrograph required for this purpose can be completed and mounted in its constant-temperature chamber on the massive concrete pier south of the polar axis.

Other elements in the design of the Hooker telescope have the same general object in view—that of developing and applying in astronomical practice the effective research methods suggested by recent advances in physics. Although most of our major instruments are now completed and in use, this policy must remain as a dominant factor in our plan of research. Fresh possibilities of progress are constantly arising, and these must be utilized as rapidly as circumstances permit. Examples have been mentioned in the solar and stellar fields, but those of the laboratory itself must not be overlooked.

The policy of providing for the interpretation of celestial phenomena by laboratory experiments was an important element in the initial organization of the Mount Wilson Observatory. Although a wide departure from the customary practice of most large observatories, it was by no means without precedent, and it certainly has been justified by results. Indeed, the development of many of our chief solar investigations would have been impossible without the aid of special laboratory studies, going hand in hand with the astronomical observations. So indispensable are such researches, and so great is the promise of their extension, that the time has come to advance them from a minor or accessory feature of the Observatory establishment to full equality with the major factors in its work.

The first step toward this end has just been taken by the purchase from the General Electric Company of a 500-kilowatt motor-generator set, soon to be installed in our Pasadena laboratory. The heavy current (D. C., 220 volts, 4,000 amperes) generated by this machine will be used in the first instance to actuate an extremely powerful electromagnet, designed by Anderson for the extension of our researches on the Zeeman effect and for other related investigations. Within the large and uniform field of this magnet, which will be built in the form of a solenoid, a special electric furnace, designed for this purpose by King, will be used for the study of the inverse Zeeman effect at various angles with the lines of force—a piece of work urgently needed to interpret certain remarkable anomalies in the magnetic phenomena of sun-spots. Furthermore, with this new and powerful equipment it will be possible to study the combined effect of magnetic and electric fields on radiation, to extend previous investigations on the spectrum of the "tube-

arc" and other special light-sources, and to complete work already well advanced on the "pole-effect" and its probable origin in the electric field. Thus the researches of King, St. John, Anderson, and Babcock can be developed on a scale commensurate with their importance. The extension of our laboratory facilities with this object in view is the next considerable task of our construction division.

Within the restricted limits of this report, it will not be feasible to enter into all the details of our future scheme of research, which has been prepared with the cooperation of the members of the Observatory staff. But we may indicate the broad lines of some of the major operations plainly indicated as both logical and necessary. In doing so, we of course have especially in mind the new possibilities afforded by the 100-inch Hooker telescope.

This powerful instrument, whose construction, after many unavoidable delays, was still further impeded by the war, is now systematically at work. In another section of this report some of the tests to which it has recently been subjected are described. So far as they have gone, they indicate that the full measure of gain over the 60-inch telescope, called for by the nearly threefold increase in light-gathering power of the larger mirror, has been attained in practice. How exacting are the conditions—optical, mechanical, and atmospheric—which must be met to permit such a gain can be appreciated only by those who have made a close comparative study of the performance of large telescopes. Perrine long since pointed out the serious enlargement of the stellar image inseparably connected with increased focal length. This, of course, is due to atmospheric disturbances, which are such as to render considerations based on the size of the true diffraction image of little meaning. In place of the minute spurious disk called for by theory, we must substitute the "tremor-disk" (to employ Newall's useful expression), which is of a very different order of magnitude. Thus, there was ample room for apprehension that with an aperture of 100 inches, and with the great equivalent focal length of 134 feet attained at the Cassegrain focus of the Hooker telescope, the images of stars might be too large, even under good atmospheric conditions, to permit them to be usefully observed. Experience has shown, however, that even at this focus the full theoretical gain in light-gathering power over the 60-inch reflector is realized in spectrographic work, and that the demand on the atmosphere is not greater than can be met on Mount Wilson during a great number of the nights of the year.

This means a gain of a full magnitude in stellar spectroscopic work, and it happens that this gain comes at a very critical point. For example, as explained on page 262, the increase in available light permits a general investigation to be undertaken of the long-period variable (Md) stars, which are beyond the reach of the 60-inch with practicable exposure times. These red stars, in addition to their peculiarities

as variables, exhibit the chemical characteristics of reduced temperatures, made familiar by our investigations of the vapors in sun-spots. While stars of this class must be studied with moderate dispersion because of their faintness, it is fortunate that we have a few examples of red stars bright enough, with the 100-inch, to permit their spectra to be critically investigated with high dispersion. For this purpose the gain of a magnitude, especially if realized at the coudé focus (equivalent focal length 250 feet), is absolutely essential. Thus, one obvious application of the Hooker telescope will be in an investigation of the red stars of various classes, both with reference to their place in the galactic system and their physical development, interpreted in the light of a comparative study of sun-spot and laboratory spectra. The proposed high dispersion work on the brightest red stars, and on other stars of the first and second magnitudes, should aid in this interpretation, and may possibly reveal minute line displacements indicating progressive changes in pressure or other physical condition characteristic of the transition from class to class.

We thus begin with a piece of research demanding the full capacity of the Hooker telescope, and intimately related to other phases of our stellar, solar, and laboratory work. Let us now consider another investigation, which can also be attacked to peculiar advantage with the Hooker telescope, especially in the light of recent important theoretical advances.

In his fundamental researches on the dynamics of rotating masses, Darwin dealt with incompressible matter, which assumes the well-known pear-shaped figure, and may ultimately separate into two bodies. Roche, on the other hand, discussed the evolution of a highly compressible mass, which finally acquires a lens-shaped form and ejects matter at its periphery. Both of these are extreme cases, hardly realized in practice. Jeans has recently dealt with intermediate cases, such as are actually encountered in stars and nebulæ. He finds that when the density is less than about one-quarter that of water a lens-shaped figure will be produced with sharp edges, as depicted by Roche. Matter thrown off at opposite points on the periphery, under the influence of small tidal forces from neighboring masses, may take the form of two symmetrical filaments, though it is not yet entirely clear how these may attain the characteristic configuration of spiral nebulæ. Jeans goes on to discuss the evolution of the arms, which will break up into nuclei (of the order of mass of the sun) if they are sufficiently massive, but will diffuse away if their gravitational attraction is small. The mass of our solar system is apparently not great enough, according to Jeans, to account for its formation in this way.

These investigations, which lead to conclusions very different from those derived by Chamberlin and Moulton from the planetesimal hypothesis, afford with the latter hypothesis valuable suggestions for a

critical study of spiral nebulæ, and also of binary systems. It is plain that the attack on the spirals should involve a study of the spectra and motions of the matter comprising the arms, as well as a determination of their parallax by any feasible means. The preliminary results of van Maanen indicate motion outward along the arms, in harmony with Jeans's views. But in order to secure a definitive answer to this critical question, a photographic campaign, including spiral nebulæ of various types, must be carefully organized with this object clearly in view. The large scale of the spiral nebulæ at the principal focus of the Hooker telescope, and the experience gained in the measurement of nebular nuclei for parallax determinations, will be important factors in this undertaking. The simultaneous spectrographic attack will be aimed, not merely toward spirals in whose plane we lie, but also toward those which stand at a sufficient angle to permit both components of motion to be measured by the two methods. In this connection the further development of the multiple-slit spectrograph, already applied at Mount Wilson in a limited way, will be essential to rapid progress.

Thus far, in our consideration of the Observatory's research program, we have dealt almost exclusively with physical problems bearing on the evolution of stars and nebulæ. In the case of the spirals, however, as in that of the red stars, it is evident that the part these objects play in the system of the universe must be answered if possible. Fortunately, the photographs obtained for the physical researches will also contribute toward this end, but they must be supplemented by others. This is especially necessary in attempting to answer the great outstanding question whether the spiral nebulæ are in reality "island universes" independent of one another and of our own sidereal system or, on the contrary, lesser systems tributary to the Galaxy, which dominates a single universe. Here a great need is for radial velocities, obtained with the most efficient spectrographs procurable, and for parallaxes derived, or at least attempted, by one or more of several methods. The 60-inch is quite as efficient as the Hooker telescope for measuring the radial velocities of the larger spirals, but for the smaller objects the latter instrument will be required.

In dealing with problems of structure and motion in the galactic system, the Hooker telescope offers some capital advantages. Hitherto all studies of stellar radial velocities have necessarily been confined to the brighter stars, in the vast majority of cases to those visible to the naked eye. These, it is true, include some very distant giant stars, but most of the stars whose radial velocities are known belong to a very limited group, perhaps constituting a distinct cluster of which the sun is a member, but in any event of insignificant proportions when contrasted with the Galaxy. Current spectrographic work with the 60-inch telescope, which will be continued as at present, includes stars of the eighth magnitude and some that are even fainter. But

while the 60-inch has enabled Adams to measure the distance of many remote stars by his new and powerful spectroscopic method, and to double the known extent (so far as spectroscopic evidence is concerned) of Kapteyn's star-streams, a much greater advance into space is necessary if we are to learn what community of motion obtains among the stars comprising the galactic system. Recent experiments encourage the hope that without inadmissible sacrifice of precision of measurement, the Hooker telescope will enable us to determine the radial velocities of stars of the eleventh magnitude, which are doubtless truly representative of the Galaxy.

In preparing an observational program to include such faint objects, the process of selection employed must be very carefully considered, in the hope of securing a maximum return within a reasonable period of time. So far as possible, the stars in Kapteyn's Selected Areas should evidently be given preference, because of the vast amount of work completed or projected for the purpose of determining their positions, proper-motions, and visual and photographic magnitudes. Considerations such as spectral type, the known directions of star-streaming, and the position of the chosen regions with reference to the plane of the Galaxy, must also be given adequate weight, though the final list should not rest too exclusively upon any hypothesis, but should contain enough widely distributed material to permit of independent statistical discussion. It is of fundamental importance that the method of spectroscopic parallaxes will permit dwarf stars to be distinguished from giant stars rendered faint by their much greater distance.

The stellar spectrograms obtained in this campaign will afford rich material for the study of many questions other than stellar distribution and star-streaming, such as the relationship between mass and speed, the nature of giant and dwarf stars, and other capital problems. The results obtained within a few years will serve as the basis for a fresh orientation, and indicate in what way the initial program of observations can be most advantageously revised.

Shapley's recent studies of globular clusters have indicated the significance of these objects in any general attack on evolutional or structural problems. The possibility of determining their parallax, by a number of independent methods, is of prime importance, both in its bearing on the structure of the universe and because it permits a host of apparent magnitudes to be at once transformed into absolute magnitudes. In the further development of this work, the Hooker telescope should be chiefly employed, partly because of the gain in light resulting from its large aperture, and also because of the increased scale of crowded clusters at the 134-foot focus, where the spectra of stars, commingled in the 60-inch, can be separately photographed. With a spectrograph of small dispersion it has already been found possible to photograph the spectra of fourteenth-magnitude stars in

the center of such clusters in less than an hour. Moreover, the style of mounting and design of dome adopted for the Hooker telescope permit it to work much farther south than the 60-inch, and thus to deal with the rich collection of globular clusters south of the equator.

Among the numerous cluster problems calling for early attack with the Hooker telescope are the detection of the faintest possible stars and the measurement of their magnitudes and colors; the determination of spectral types, and of the radial velocities of individual stars and of clusters as a whole; a search for spectroscopic evidence of possible axial rotation of globular clusters; and the development and application of all available means of determining the distances of clusters, particularly the method of spectroscopic parallaxes.

The possibility of dealing with many problems relating to the distribution and evolution of the faintest stars depends upon the establishment of photographic and photovisual magnitude scales. Below the twelfth magnitude the only existing scale of standard visual or photovisual magnitudes is the Mount Wilson sequence, already carried by Seares to magnitude 17.5 with the 60-inch telescope. The extension of this scale to still higher magnitudes, and its application to the study of the faintest stars within its range, is an important task for the Hooker telescope. There is good reason to believe that this instrument will bring into view hundreds of millions of stars beyond the reach of the 60-inch. The giants among these will form for us the outer boundary of the galactic system, while the dwarfs will be of almost equal interest from the evolutional standpoint. Such questions as the condensation of the faintest stars toward the galactic plane, the color of the most distant stars, and the final settlement of the long inquiry regarding the possible absorption of light in space, are among those to be dealt with in the photometric field.

It is clear that such activities as those already enumerated will heavily tax the capacity of the Hooker telescope. But certain special studies of exceptional promise must also be undertaken if possible. One of these, which will be greatly facilitated by the large aperture, is the determination of the spectral-energy curves of stars of various classes, for the purpose of measuring their surface temperatures. This is obviously of great importance in a general study of stellar evolution. Other special investigations dealing with variable and temporary stars, the peculiarities of variable nebulæ, and the spectra of the components of close double stars will be discussed in future reports.

In all of this work, the desirability of cooperating with other institutions and of limiting our observations, so far as may be practicable, to those which can be undertaken to exceptional advantage by our staff and equipment, must be constantly borne in mind. Several important cooperative arrangements have already been made with other observatories, and others are now in prospect.

STAFF.

The Director, after attending international scientific conferences at the Royal Society in October and the Paris Academy of Sciences in November, returned to the United States in December, and continued his work as Chairman of the National Research Council. On April 30, 1919, he resigned the chairmanship of the Council and returned to Pasadena, where he has since devoted all of his time to the work of the Observatory. Dr. Walter S. Adams, Assistant Director, who continued in general charge of the Observatory during the Director's absence, carried forward his investigations in stellar spectroscopy until June 1919, when he went to Europe as a member of the American delegation to the Brussels meeting of the International Research Council. Professor F. H. Seares, superintendent of the Computing Division and editor of the Observatory publications, continued his researches in stellar photometry and his investigations of the general magnetic field of the sun until June 1919, when he went abroad with the Assistant Director as a member of the American delegation to Brussels. Dr. Arthur S. King, superintendent of the Physical Laboratory, devoted about half his time prior to the armistice to experiments on projectiles and tests of optical glass. He has since continued his spectroscopic investigations with the electric furnace, including studies of the Zeeman effect in a small furnace placed between the poles of a magnet. Dr. C. E. St. John continued his spectrographic investigations on the solar rotation, the determination of solar wave-lengths, and the displacements of the lines in the spectrum of Venus until June, when he went with Dr. Adams and Professor Seares to the Brussels meeting of the International Research Council. Dr. J. A. Anderson devoted all of his time to experimental researches for the Navy up to the time of the armistice; since then he has resumed his investigations on the effect of an electric field on radiation, designed a powerful electro-magnet for the laboratory, and continued his tests of the ruling-machine with Mr. Jacomini. Professor Ritchey has given most of his time to optical work for the Ordnance Department of the Army. Mr. Harold D. Babcock, after the conclusion of his experimental work for the Navy with Dr. Anderson and Professor Ryan, has continued his investigations on standard wave-lengths and undertaken a study of the polarization of the night sky at the request of Lord Rayleigh. Mr. Ferdinand Ellerman has continued his solar observations and his work as Observatory photographer. Mr. Francis G. Pease, after returning from his duties in Washington with the National Research Council, has continued his work of instrument design and his photographic observations of nebulæ and star-clusters. He has also given much time to the adjustment and tests of the 100-inch Hooker telescope. Dr. Harlow Shapley has continued his investigations of star-clusters and variable stars and his researches on various sidereal problems. Dr. Adriaan

van Maanen has carried forward his determinations of stellar parallaxes and proper-motions, and has continued the measurement of spectra to fix the position of the sun's magnetic axis. Professor Alfred Joy has continued his stellar spectroscopic investigations. Dr. Paul Merrill, who joined the staff of the Observatory in January, has divided his time between laboratory investigations and stellar spectroscopy. Dr. Gustaf Strömberg has given special attention to investigations on the relation of mean stellar parallaxes to mean proper-motion and on systematic corrections to the absolute magnitudes of stars as determined spectroscopically. Dr. R. F. Sanford has continued his investigations in stellar spectroscopy and on the spectra of nebulæ and star-clusters. Mr. Frederick Brackett joined the staff on June 1 as assistant in the solar observations. Messrs. Hugo Benioff, Clarence Henshaw, and Sinclair Smith have served as assistants during a part of the year.

Professor J. C. Kapteyn, Research Associate of the Carnegie Institution, has continued in Groningen his investigations in cooperation with the Observatory. Professor A. A. Michelson, recently appointed Research Associate of the Carnegie Institution, is preparing apparatus for use on Mount Wilson in measuring the diameter of stars by interference methods.

The members of the Computing Division have assisted in the work of the various departments as follows: Miss Ware and Miss Miller have been engaged in solar and laboratory investigations under the direction of Mr. St. John, Miss Ware devoting her time mainly to the rotation of the sun. Miss Burwell has divided her time between the classification of stellar spectra and the spectroscopic determination of stellar parallaxes, together with the measurement and reduction of stellar spectrograms for radial velocity. Miss Brayton and Miss Shumway have been engaged wholly with determinations of radial velocity. Miss Margherita Burns has given her entire time to the measurement and reduction of spectra secured in the physical laboratory for the determination of standards of wave-length. Miss Davis, and later Miss Ritchie, have been occupied with various investigations relating to star-clusters. Miss Joyner and Miss Richmond have devoted most of their time to stellar photometry. Miss Joyner has also assisted in the library, and Miss Richmond has made numerous miscellaneous measures and reductions of stellar positions. Miss Wolfe has been engaged in computations of parallax and proper-motion and in reductions connected with the general magnetic field of the sun. She has also made photographic reproductions of many of the solar negatives. Miss Connor has continued as librarian, and has assisted with the editorial work.

Miss Davis resigned in September 1918, and Miss Burns in July 1919. Miss Mary Ritchie was appointed in April 1919.

Father Luis Rodés spent the greater part of the year as a volunteer assistant at the Observatory, returning to Spain in July. From October 1 to May 1 he assisted in the photographic work with the 60-foot tower telescope. Mr. Toshio Takamine, of the University of Tokyo, spent the period September 1918 to April 1919 as volunteer assistant in the Physical Laboratory, where he conducted an investigation on the effect of an electric field on metallic spectra. Dr. John C. Duncan, director of the Whitin Observatory, Wellesley College, came to Mount Wilson for stellar spectrographic work and the photography of nebulæ during the summer of 1919. Mrs. Harlow Shapley, volunteer assistant, has continued to collaborate with Dr. Shapley in his stellar investigations. Miss Edna Carter, associate professor of physics at Vassar College, returned for the summer of 1919 as volunteer assistant in the Physical Laboratory, where she has continued her studies of metallic spectra produced by the cathode discharge.

Mr. L. B. Aldrich had charge of the work of the Smithsonian Astrophysical Observatory on Mount Wilson during the summer of 1919.

INVESTIGATIONS IN PROGRESS.

SOLAR RESEARCH.

The 30-foot vertical spectrograph, designed for use in conjunction with the remodeled Snow telescope, has been completed and employed for certain investigations mentioned in the present report. A new form of measuring machine, involving the principle of the heliometer and especially applicable to differential measurements of photographs of the Zeeman effect in sun-spots, has been constructed after designs by Mr. Anderson.

SOLAR PHOTOGRAPHY.

During the year ending August 31, 1919, the following solar photographs were taken with the 60-foot tower telescope by Messrs. Ellerman, Nicholson, Rodés, Benioff, Henshaw, Brackett, and Baker:

Photoheliograms of 6.5 image, 340 on 325 days.
Spectroheliograms with 5-foot spectroheliograph (H_α, entire 6.5-inch disk), 191 on 191 days.
Spectroheliograms with 13-foot spectroheliograph (K and $H\alpha$, 2-inch disk and prominences; $H\alpha$, portions of 6.5-inch disk, monochromatic light from continuous spectrum), 1,177.

Photographs of spectra taken with the 75-foot spectrograph of the 150-foot tower include 102 exposures for solar rotation (Mr. St. John), 53 exposures for motion in sun-spots (Mr. St. John), and 40 for the investigation of magnetic fields in sun-spots and at other points on the disk (Mr. Ellerman, Mr. Nicholson, and Mr. Brackett). Some of these photographs, made with the assistance of Mr. Merrill on plates sensitized with dicyanin, kindly furnished us by the Bureau of Chemistry of the Department of Agriculture, extend our records of sun-spot spectra into the infra-red as far as $\lambda 7900$.

Photographs of spectra taken with the new vertical spectrograph of the Snow telescope include:

Venus	54
Sun	17
Sky	31
Sun with interferometer	25

SUN-SPOT ACTIVITY.

The calendar year 1918 showed a marked decline in sun-spot activity, 314 groups having been observed as against 450 during 1917. There were no spotless days during the year, although about the middle of June there were several days on which only two groups were recorded. In contrast with this quiescent period, the first two days of June, judged by the number of individual groups, were the most active of the year. Sixteen spot-groups were recorded on each of these days. The following table gives the average number of groups observed per day during each month:

Month.	Daily number.	Month.	Daily number.
January	8.3	July	8.2
February	6.3	August	7.3
March	5.9	September	5.9
April	7.0	October	6.5
May	6.8	November	6.0
June	6.6	December	4.8

The average latitude of all groups observed during the year was 13°, 2° less than the average for 1917.

SUN-SPOT POLARITIES.

The results of the investigation referred to in the last annual report have been published by Messrs. Hale, Ellerman, Nicholson, and Joy in Contribution No. 165 on "The Magnetic Polarity of Sun-spots." This paper describes the methods of observation employed in obtaining a daily record of the polarities of all spots with the 75-foot spectrograph of the 150-foot tower telescope; the precautions that must be taken to avoid error in the case of spots near the limb; the method of measuring the inclination of the lines of force in sun-spots, in planes parallel and at right angles to the line of sight; and a method of classifying sun-spots on the basis of their magnetic properties. The paper includes a magnetic classification of 970 spots observed during the years 1915, 1916, and 1917, and discusses the results of the observations made during this period. About 60 per cent of all sun-spots are found to be binary groups, the single or multiple members of which are of opposite magnetic polarity. Unipolar spots are very seldom observed

wave-length is shown by the bolometric work of Abbot and by the observations of Schwarzschild and Villiger, who photographed a small image of the sun through a silver film transmitting light of λ3200. It occurred to the Director that this method, if applied on a sufficiently large scale, might aid in accomplishing two objects: (1) the better detection of the "faint markings" or minute spots found by Maunder at Greenwich in very high solar latitudes and also of possible faint spots in bipolar groups that appear unipolar in ordinary photographs; and (2) the enhancement of the contrast in the photospheric structure to a degree sufficient to permit better study of the granulation. In order to test the method for these purposes, small plane speculum metal mirrors were figured in our optical shop and mounted on the cœlostat and in front of the second mirror of the Snow telescope. A concave speculum metal mirror of 60 feet focal length was also prepared and mounted in front of the large concave mirror. The light from the silvered surfaces of the large mirrors was completely cut off, and the solar image, 6.5 inches in diameter, was thus formed by the light from the speculum metal mirrors, which have a fairly high coefficient of reflection in the ultra-violet. A thin piece of plane glass, found to transmit ultra-violet light of λ3200, was silvered on one face and mounted in front of the photographic plate, at a distance of about 20 inches.

Photographs of the photosphere and spots made with this apparatus do not as yet show the increased contrast expected, but the method seems of sufficient promise to warrant further development.

PECULIARITIES OF THE CENTRAL LINES OF ZEEMAN TRIPLETS IN SUN-SPOT SPECTRA.

The fact has been mentioned in previous reports that the central or *p*-component of many sun-spot triplets does not behave as theory and laboratory experience would lead one to expect. When the spectrum of a large spot not too far from the center of the disk is photographed with the Nicol and compound quarter-wave plate, the outer or *n*-components of the Zeeman triplets are alternately cut off on successive strips of the quarter-wave plate, while the *p*-component is transmitted with intensity which varies across the spot. If, as theory and laboratory experience would indicate, the *p*-component were plane polarized, it should show no relative displacements on adjoining strips. As a matter of fact, however, it does show such displacements, opposite in sign to that of the *n*-components. That is, on a strip where the red *n*-component is weakened and completely cut off, the *p*-component is slightly displaced toward the red.

The degree of this displacement and its relationship to the separation of the *n*-components (which indicates the strength of the field at this level in the sun-spot) have been measured by the Director and Mr.

Brackett in a number of the best spot triplets. The results indicate that while there may be very appreciable differences of behavior in different triplets, the shift of the p-component is in general smallest near the center of the spot, and approaches a maximum near the outer edge of the penumbra, where the field is very weak. Thus, both in sign and magnitude of displacement, the p- and n-components behave in opposite ways. The investigation is being followed up, both on the solar and laboratory sides.

In this connection we may recall the existence of other anomalies in the Zeeman effect, as observed in the sun-spot spectrum. A notable instance is that of the vanadium line λ6111.872, which Mr. Babcock's photographs show to be a quadruplet in the spectrum of a spark between the poles of a magnet, with the p- and n-components exactly superposed. In sun-spots this line appears to have a more complex structure, but the separation of the components is not sufficiently complete to permit their character to be determined with certainty. Other interesting cases, soon to be described in detail, might also be mentioned as valuable guides to further laboratory research. When viewed in contrast with the line-for-line agreement, in the vast majority of instances, of the Zeeman effect in sun-spots and in the laboratory, these few exceptions assume special interest and will warrant careful study by physicists.

INCLINATION OF THE SUN'S MAGNETIC AXIS.

The first series of observations for the location of the sun's magnetic axis, made on 74 days between June 8 and September 25, 1914, have now been completely reduced for the determination of mean values of the magnetic elements. The results are based on the assumption that the sun is a uniformly magnetized sphere. The measures, as in previous years, have been made by Mr. van Maanen. The reductions by Miss Wolfe, carried out under the direction of Mr. Seares, have given the following results:

$i = 6.0 \pm 0^\circ\!.4$ $\quad$ $P = 31.52 \pm 0.28$ days.
$t = 1914$, June 25.38 ± 0.42 days, G. M. T.
$k = 0.99$ (a constant inversely proportional to the polar field-strength).

The probable error of the period of revolution of the magnetic axis about the sun's axis of rotation is naturally large because of the short interval covered by the observations. A comparison of these results with a short series of observations in September 1916 indicates, however, that the period itself is near the true value. The complete reduction of the 1916 series, which is now in progress, should reduce the uncertainty in the period well below a tenth of a day and make it possible to carry the longitude of the pole forward, without ambiguity as to the number of revolutions, to the coming sun-spot minimum, when further observations can be undertaken without risk of interference from the magnetic fields of the spots.

When the measures are discussed by zones for the purpose of detecting deviations from the uniform field presupposed in deriving the above elements, it is found that the inclination of the magnetic axis is sensibly constant between latitudes 45° N. and 45° S. and equal to about 4°. The polar field-strength, however, seems to change rapidly with the latitude, the result from the equatorial zone being nearly twice that found for the zones 10° to 45°.

SOLAR ROTATION.

The differences between the rotation values for the earlier and later portions of the 20-year period now covered by spectrographic observations remain an outstanding feature of the problem. An extended series of observations taken under uniform conditions seems still the most promising mode of attack. Such a series, for which the 150-foot tower telescope is used, is now in its sixth year at Mount Wilson. These observations by Dr. St. John show practically the same period of rotation for each of the six years from 1914 to 1919.

An important modification in method made during the year consists in observing the center of the disk simultaneously with the two limbs. The positions of the solar lines in spectra of the sun's center are remarkably constant, but the differences found by comparing the east and west limbs with the center often differ by 10 or 15 per cent of the differences at the equator. The observations also show that high values at one limb are not correlated with high values at the other, as would be the case if the variations at the limbs were due to changes in the rotation period of the reversing layer or to conditions in the terrestrial atmosphere. The observations of the present year confirm the earlier evidences of local disturbances in the reversing layer, and indicate further that they are frequent at all latitudes, and that the motions of the vapors are tangential. Evidence is accumulating which tends to show that the motions in the reversing layer around spots and pores are similar in character. Simultaneous observations at the center and limbs provide a valuable means of checking results and of investigating the hemispheres separately, and give also as a by-product the limb-effect at different latitudes. The means from 172 observations on a group of 10 lines give, within the precision of measurement, equal values for the displacements between limb and center in both hemispheres and at all latitudes. The result is of importance in the intensive study of the limb-effect to be undertaken at Mount Wilson.

Further tests at Mount Wilson of the effect of integrated sky-light in line displacements at the sun's limb show that the integrated light just outside the solar image is not of sufficient intensity to affect the photographic plate during the exposure time employed for solar-rotation observations, that it requires marked cloudiness over and

around the sun, conditions never approximated in regular work, to cause a measurable decrease in the line displacement at the limb, and that this large proportion of superposed sky-light produces no differential effect between strong and weak lines.

WAVE-LENGTHS IN SPECTROGRAMS OF VENUS.

Evershed has suggested, as an explanation of his observations, that the wave-lengths in light reflected by Venus vary with the relative positions of Venus, the Sun, and the Earth.

Several spectrograms of Venus, with an average exposure of one hour each, have been secured at Mount Wilson by Mr. St. John and Mr. Nicholson in the first order of the 18-foot grating spectrograph, using the iron-arc for comparison. Wave-lengths of 43 lines in the nighborhood of $\lambda 4500$ in the spectrum of Venus have been compared with those of the same lines in the spectrum of the sky and of the center of the sun. Measures of 18 sky plates and 9 solar plates show no difference between wave-lengths in the spectra of these two sources.

Twenty-six of the Venus plates have been measured, for which the angle Venus-Sun-Earth changed from 102° to 32°. The spectra taken with Venus at an altitude of 30° give approximately the same wave-lengths as the sky spectra, but for lower altitudes the wave-lengths of Venus are shorter, irrespective of the relative positions of Venus, the Sun, and the Earth. As it was possible that at low altitudes atmospheric dispersion might produce a non-uniform illumination of the slit, the spectrograph was rotated 180° between exposures. The following table gives a brief summary of the present results. Since the dispersion was 3 A per mm., these residuals are near the limit of measurement.

Altitude.	Residual Venus and sky.	Angle, V. S. E.	No. of plates.
12°	−0.004 A	80°	5
18	− .005	42	6
19	− .005	98	5
27	− .002	80	5
30	+0.001	64	5

The observed variation in wave-length may be due to some uneliminated instrumental error connected with the low altitude of Venus. At any rate, it will be necessary to secure more plates with Venus on the other side of the sun before the observations can be definitely interpreted.

WAVE-LENGTHS OF ATMOSPHERIC ABSORPTION LINES.

Some observations by Perot seem to show a variation of the wavelengths of the absorption lines of oxygen with the altitude of the sun which would indicate a recession of the absorbing centers with a velocity

of 3 km. per second. The accompanying observations, made by Mr. St. John at Mount Wilson with the grating spectrograph, show no change in the wave-lengths of the atmospheric lines from sunrise to sunset.

Wave-lengths of atmospheric lines of oxygen.

6 a. m.	9 a. m.	12 m.	3 p. m.	6 p. m.	Mean.
6280.401	.402	.401	.400	.399	.401
6281.184	.186	.185	.185	.183	.185
6281.961	.962	.963	.962	.961	.962
6290.230	.230	.230	.230	.229	.230
6295.186	.184	.187	.186	.187	.186
6295.968	.968	.969	.969	.969	.969
6302.008	.006	.009	.006	.009	.008
6302.769	.769	.772	.768	.771	.770

Since it has long been customary to employ the absorption lines of our atmosphere as fixed standards of wave-length in measurements upon solar and stellar spectra, it seemed desirable that the question should be independently examined by Mr. Babcock in Pasadena, using interference methods. Observations were accordingly carried out during March and April, using for the most part the α group of air-lines having its head at λ6276. Instrumental conditions were favorable to the detection of very minute displacements of the spectral lines, but no evidence was found of diurnal variation of wave-length. This is in agreement with Mr. St. John's work with the grating, and it is hard to account for the discordance between these results and those of M. Perot, whose data indicated daily variations amounting to about 0.030 A for lines of the B group.

SOLAR WAVE-LENGTHS WITH THE INTERFEROMETER.

Preliminary work on the application of the interferometer to certain classes of solar observations was begun by Mr. Babcock during the summer, using the Snow telescope in conjunction with the new vertical spectrograph recently completed. The aim has been to ascertain the best working conditions and the reliability of the results obtained when wave-lengths are observed at the center of the sun. The photographs are also being used for further study of the wave-lengths of atmospheric absorption lines. Up to the present, the auxiliary dispersion has been produced by a 7-inch grating having an extremely bright first-order spectrum, used at the 18-foot focus of the auto-collimating spectrograph. Plates of excellent quality have been obtained, on which the definition is satisfactory over 100 A. The few measurements made thus far indicate that, for good solar lines of medium intensity, the relative wave-lengths can be depended on to about 0.001 A, *i.e.*, the accuracy is about the same as in the grating method. Further tests are to be made with the aid of higher auxiliary dispersion

provided by using the same grating at the 30-foot focus of the spectrograph in conjunction with the same interference apparatus as before. The flatter field of the long-focus lens, combined with the increased auxiliary dispersion and greater slit-width required, should prove of material assistance in such observations.

POLARIZATION OF THE NIGHT SKY.

At the request of Lord Rayleigh (then Professor Strutt) observations were begun by Mr. Babcock during the past spring with a view to finding out whether the background of the night sky, which is by no means absolutely black, consists of scattered sunlight. Theoretical considerations as well as laboratory data have shown that if such is the case, the feeble light which constitutes this background will be polarized in a plane passing through the sun, even though the scattering be produced by hydrogen extremely attenuated. A large Savart polariscope was loaned to us by Lord Rayleigh for making the observations, but a smaller instrument, more economical of light and at the same time more sensitive than the Savart polariscope, was developed in our laboratory and used instead. The photographs were taken with every precaution to eliminate false effects. They extended over a period of 4 or 5 months, and 8 plates were secured under conditions thought to be satisfactory for the purpose. These photographs indicate that practically none of the light in the background of the night sky is polarized.

INVESTIGATION OF STARS AND NEBULÆ.

OBSERVING CONDITIONS.

The observing conditions at night on Mount Wilson for the year ending August 31, 1919, are indicated by the accompanying tables prepared by Mr. Hoge, night assistant at the 60-inch reflector. The data show conditions slightly above the average for the past 7 years. Observations were carried on during all of 204 nights and a part of 97 nights. On 64 nights no observations were made on account of the weather. The 60-inch telescope was in use a total of 2,378 hours, which is 66 per cent of the total hours of darkness. The total exposure time for the year was 70 per cent of the available observing weather and 46 per cent of the total hours of darkness. The month of June gave 100 per cent of observing weather at night. This is the first time our records show the nights of any calendar month to have been entirely free from clouds. The telescope was in use during the whole of each night from May 31 to July 15 inclusive, 46 consecutive nights, the longest uninterrupted observing period we have recorded.

The past year was the driest since the beginning of our record 15 years ago. The total precipitation was 20.62 inches, which is 13.69 inches below the normal. The total snowfall was 55 inches. A very severe and remarkable wind-storm occurred on November 24, 1918,

when a maximum velocity of 90 miles per hour was recorded at the top of the 150-foot tower telescope. The gale lasted for 52 hours, during which time the average velocity was 50 miles per hour. For one period of 5 hours an average velocity of 75 miles was maintained. All of the buildings of the Observatory withstood the gale without damage, but several large pine trees near the 100-inch dome were uprooted. The average wind velocity for the year was 11 miles per hour. The highest temperature for the year was 100° F., on August 21, the highest on record; the lowest was 16° F. on December 31. The tables give statistics for each month, the conditions of seeing (on a scale of 10), and the wind velocity.

Seeing.		Wind.	
Scale.	No. nights.	Velocity.	No. nights.
1	44	High.......	22
2	54	Brisk.......	34
3	33	Moderate...	48
4	50	Light.......	153
5	52	Calm.....	92
6	22	....	....
7	13	....	....
8	3	....	....

Month.	Hours of darkness.	Hours clear.	Hours cloudy.	Hours lost silvering and repairs.	Hours of exposure time.	Observations.		
						All night.	Part of night.	None.
1918.								
September....	295	203	92	....	129	16	10	4
October.......	336	216	119	1	134	14	13	4
November....	330	168	162	....	104	13	7	10
December.....	346	204	142	....	144	13	11	7
1919.								
January.......	346	187	159	....	140	9	15	7
February.....	308	129	179	....	93	7	10	11
March......	324	188	136	....	135	11	14	6
April........	286	174	103	9	139	16	6	8
May..........	266	193	3	....	132	21	4	6
June.........	230	230	70	....	173	30	0	0
July...........	255	235	20	....	165	27	4	0
August.........	269	251	18	....	170	27	3	1
Totals for year.	3,591	2,378	1,203	10	1,658	204	97	64
Mean for 7 years......	....	2,298	1,286	....	1,623	191	92	82

PHOTOGRAPHS OF NEBULÆ AND CLUSTERS.

Mr. Pease has duplicated with the 60-inch reflector many photographs of nebulæ taken in 1917-18 and has obtained negatives of the following additional objects:

N. G. C. 48, 49, 50. Group of 11 small nebulæ, 9 elliptical, 2 irregularly round.
N. G. C. 3786 and 3788. Right-handed spirals just touching; 27 additional nebulæ on plate.
N. G. C. 4395–99, 4401. Remarkable spiral nebula, suggesting superposition of two spirals, or a secondary center.
N. G. C. 4656–7. Right-handed spiral, one arm well defined, other diffuse.
N. G. C. 5278 and 5279. Two small left-handed spirals.
N. G. C. 5278–9. Right-handed spiral with one arm.
N. G. C. 5868. Small round nebula.
N. G. C. 5869. Small elliptical nebula.
N. G. C. 6823. Cluster.
N. G. C. 6927, 6928, 5930, etc. Field of 7 small spirals.
N. G. C. 7626, etc. Field of many small stellar and spiral nebulæ.
I. C. 917–938. Field of many small nebulæ.

Slight changes have been observed in N. G. C. 1555, but none that is certain in N. G. C. 2245.

Mr. Sanford has made 6 photographs of Nova Aquilæ No. 3, with exposure times ranging from 75 to 390 minutes. No evidence of nebulosity about the star had been found up to June 1919, when the last photograph was made. During 1918 the exposures were necessarily limited in length, owing to the brightness of the star.

From a series of 18 photographs of the Andromeda Nebula, made on Seed 30 plates with exposure times averaging about 30 minutes each, Mr. Sanford has discovered 4 additional Novæ, Nos. 10, 11, 12, and 13; a fifth Nova has been found by Mr. Duncan.

Mr. Duncan has made 14 photographs of nebulæ with the 60-inch reflector, including exposures of 2 hours or more upon the objects N. G. C. 6703, Messier 8, Messier 17, and Messier 31.

STELLAR PARALLAXES AND PROPER MOTIONS.

During the period September to June, Mr. van Maanen made 347 negatives with 510 exposures at the 80-foot focus of the 60-inch reflector; 267 of these, including 428 exposures, were made for parallax measures, and 80, with 82 exposures, were made for the determination of proper motions. During the absence of Mr. van Maanen in July and August, Mr. Benioff made 62 negatives, 40 for parallax and 22 for proper motion, with a total of 92 exposures.

Mr. van Maanen has completed the measures and reductions for 20 parallax fields, thus giving a total of 100 fields finished to date.

The parallaxes of 3 additional planetary nebulæ were also determined, viz, N. G. C. 6804, 6905, and 7008. The relative values were found to be $+0''.020$, $+0''.013$, and $+0''.014$, respectively. If these results are combined with those for N. G. C. 2392, 6720, and 7662, given in the last report, we are led to the following conclusions regarding these remarkable objects:

The mean absolute magnitude of the central stars is $+9.1$. This is noteworthy because the spectra of these objects consist in many cases chiefly of bright lines, whereas, in the case of stars, bright-line spectra

are chiefly associated with high luminosities. On the other hand, assuming the relationship between luminosity and radial velocity found for the stars of advanced spectral type to apply also to planetary nebulæ, the high radial velocities observed for these objects, averaging about 29 km. per second, are in harmony with their low intrinsic brightness. The mean diameter of the 6 planetary nebulæ for which parallaxes are now known is 4,000 astronomical units or 0.06 light year.

For the F-type star of magnitude 12.34 and annual proper motion 3''.01, found by Mr. van Maanen in 1917, a relative parallax of +0''244 has been derived, corresponding to an absolute magnitude of +14.3 photovisual, or +14.8 photographic. It appears, therefore, to be by far the faintest F-type star known at present. If its surface brightness be assumed to correspond with the average for F-type stars in general, the observed parallax gives a diameter no greater than that of the earth.

Two fields have been examined by Mr. van Maanen for proper motion:

(1) A region in the Pleiades, for which a plate taken in 1913 at the 80-foot focus of the 60-inch telescope was compared with two exposures made in 1918. 85 stars were measured, the faintest being of photographic magnitude 15.7. In order to secure the best results, the quadratic terms in x and y were not neglected in the reductions. The proper motions resulting from two pairs of plates may be estimated to have a probable error in each coordinate of 0''.018 divided by the number of years in the interval. Of the 85 stars measured, only 5 show proper motions equal to that of the Pleiades; the faintest of these is of photographic magnitude 13.7. Adopting 0''.015 as the parallax of the group, the absolute magnitude of this star is +9.6, as contrasted with −0.9 for the brightest star of the Pleiades.

(2) A region in the Orion Nebula. Mr. van Maanen's measures of two pairs of plates taken with the 40-inch Yerkes refractor were improved by using the quadratic terms in x and y, a magnitude correction, and a correction from relative to absolute motion. The results show that the refractor plates, as well as those made with the reflector, require the use of quadratic terms.

Assuming that the numerous variable stars in this region belong to the Orion Nebula and move with it, the resulting proper motion of the nebula is 0''.006 in position angle 110°. The background stars seem to show a decided preferential motion in the direction of Kapteyn's first stream. Much more material for different parts of the sky will of course be necessary before any conclusions can be drawn regarding the participation of stars as faint as the fourteenth and fifteenth magnitudes in the stream-motion.

The absolute magnitudes and masses were determined for 37 visual binaries, for which both the orbits and the parallaxes are known with at least fair accuracy. The results show clearly a relationship between mass and absolute magnitude.

STELLAR PHOTOMETRY.

The observational part of the investigations in stellar photometry by Mr. Seares and Mr. Shapley includes 465 photographs, all made with the 60-inch reflector and distributed as follows: Selected Areas, 113; clusters, 175; color photographs of stars, 125; miscellaneous, 52.

PHOTOGRAPHIC MAGNITUDES FOR THE SELECTED AREAS.

The observational program was finished by Mr. Seares early in the year. Final magnitudes based on a normal scale and referred to the international zero-point are now available for Areas 1 to 91. The relative magnitudes for Areas 92 and 139 are complete. With the exception of 6 plates, the intercomparison photographs for the latter group of areas have been completely measured and reduced. The correction of the relative magnitudes for zero-point can therefore be undertaken almost immediately. The addition of the reduction constants will complete the photometric part of the program for the photographic magnitudes. Coordinates sufficient for purposes of identification of the stars are already in process of determination. Results for Areas 1 to 22 are available at present.

Miss Joyner and Miss Richmond have given the greater part of their time to the measures and reductions connected with this investigation.

PHOTOVISUAL MAGNITUDES FOR THE SELECTED AREAS.

This investigation, as outlined in previous reports, has been continued by Mr. Seares and Mr. Shapley, and 159 of the 257 photographs required have now been obtained. The measures of the plates are nearly complete to date.

RELATION OF THE COLOR OF STARS TO THEIR INTRINSIC BRIGHTNESS.

The measurement of the color of stars by the method of exposure ratios has been continued by Mr. Seares for the purpose of determining the relation of color to intrinsic brightness in objects of the same spectral class. The faintness of the violet end of the spectrum of the giant stars of the later types has been known for some years. The observations confirm this result for the G and K stars, and afford a quantitative determination of the dependence of color upon absolute magnitude. The M stars, however, seem to have nearly the same color, whatever their luminosity.

Preliminary results for B, A, and F stars have also been obtained. The very luminous B's seem to be redder than those somewhat fainter,

although the result requires confirmation. The A's, however, at least from A3 on, behave in an opposite manner, the stars of high luminosity being very definitely bluer than fainter objects of the same spectral class. For F stars the relation is a transition from the characteristics of the A's to those of the G's. With increasing absolute magnitude the color first changes toward red and then, as the lower luminosities are approached, shifts back toward the blue.

Since most of the brighter stars are giants, the variation of color-index with spectral type hitherto found refers to stars of high luminosity. For stars of zero absolute magnitude, the present observations agree with previous results in showing a change in color-index, which, as far as K5, is nearly proportional to the change in spectrum. Beyond this point, through spectral classes Ma, Mb, and Mc, the color of the giants remains sensibly constant. For the dwarfs, the variation of color with spectrum is much less regular, and can not be inferred from the numerical results hitherto available.

Investigation of Star-Clusters.

In continuation of his systematic photometric study of stellar clusters, Mr. Shapley has completed a special investigation of the typical globular cluster Messier 68 (N. G. C. 4590). All the characteristic conditions and laws previously found in the study of other globular systems are without exception verified by the work on this cluster. The results include the verification of (1) the color law for giant stars in clusters; (2) the constancy of the median magnitude of cluster-type variables; (3) the numerical relation of the median magnitude to the mean magnitude of the brighter stars; (4) the anomalous form of the general luminosity curve in stellar clusters; and (5) the applicability of luminosity methods to the determination of distances.

A preliminary determination of the distances of 70 open clusters has been made on the basis of (1) 30 spectrograms of some 200 faint stars in various northern groups, obtained with a slitless spectrograph of small dispersion at the 80-foot focus of the 60-inch reflector; (2) more than 100 direct photographs at the primary focus of the 60-inch; (3) magnitudes and colors of about 2,000 stars; and (4) the measurement of the diameters and form of all known open clusters on Franklin-Adams charts, Harvard photographs, or Mount Wilson plates. The study of the distribution of these open systems in space throws some light on the structure of the nearer parts of the galactic system, and supports the hypothesis that light from the most distant objects along the galactic plane may be obstructed by dark nebulous matter.

In last year's report mention is made of the possibility of interpreting star-streaming, as well as the decrease of stellar density with distance from the sun, as phenomena connected with the translational and rotational motions of a large local cluster situated in the star-fields of the

greater galactic system. Stars of spectral type B are especially suitable for determining the extent and position of this local cluster. Assisted by Miss Richmond, Mr. Shapley has studied diagrammatically the distribution of B stars on the surface of the sky, showing that those fainter than apparent magnitude 7 are practically all concentrated narrowly to the galactic circle, while all but a few of those brighter than apparent magnitude 6 show independence of the galactic circle and a distinct concentration to the equator of the flattened local cluster. In the part of the sky where the circles of the Galaxy proper and the local cluster appear most widely separated, the projection on the sky of stars of the local cluster gives rise to a faintly visible secondary Milky Way. These new results support both the hypothesis of the existence of a local cluster or cloud and the related theory of star-streaming.

In a series of nine short papers printed together as Mount Wilson Contribution No. 161, Mr. and Mrs. Shapley have continued their study of the structure of the galactic system. An interesting part of this work relates to the distribution of spirals and to certain properties of their systematic recessional motion, suggesting that the whole galactic system may be rapidly moving through space. Apparently the spirals are not distant stellar organizations or "island universes," but truly nebular structures of great volume which in general are actively repelled from stellar systems. A tentative cosmogonic hypothesis has been formulated to account for the motions, distribution, and observed structure of clusters and spiral nebulæ. For the purpose of further testing the premises and conclusions of the proposed interpretation, various investigations have been taken up, among which the following are the most significant: (1) a search for additional globular clusters, which so far has yielded 17 extremely distant systems; (2) the verification of the method of diameters in the estimation of distances of globular clusters; (3) the successful use of the integrated magnitudes of clusters as criteria of distance; (4) a discussion of the dimensions of the local cluster, as shown by the spectral data in the Henry Draper Catalogue; (5) the frequency of various absolute magnitudes in clusters, including an attempt to ascertain the relative number of dwarf stars; (6) an inquiry into the radiation of stellar energy, with a consideration of its bearing on the speed of spectral evolution (as illustrated by phenomena of globular clusters and Cepheid variables) and on the age of the sun and the earth.[1]

VARIABLE STARS.

A theoretical investigation by Mr. Shapley and Mr. Nicholson of the form of the spectral lines of a spherically pulsating star bears on the hypothesis that pulsations of single stars underlie the numerous phe-

[1] Publications of the Astronomical Society of the Pacific, October 1918, and June 1919; Nature, March 13, 1919, and June 12, 1919.

nomena of Cepheid variations. Among other results it is found that in the broadening of spectral lines for a Cepheid variable, rotation may easily play a larger part than pulsations; also spectrographic resolution, photographic technique, and the inherent width of a spectral line all contribute to the concealment both of the broadening and the asymmetry which affect the lines of a pulsating star. It is concluded that the observed appearance and behavior of the spectrum of a Cepheid variable is not opposed to the hypothesis of pulsations.

During the year Mrs. Shapley has studied the orbits of various eclipsing binaries. An analysis of the system of Y Leonis, based upon observations by Luizet, indicates that this is one of the few eclipsing stars whose light-curve does not permit a solution on the assumption of darkening at the limb which is as good or better than that resulting from the assumption of uniformly luminous disks. In parallax, absolute magnitude, and spectrum of the binary, in the dimensions, mean density, and surface brightness of its two components, and in the various properties of the orbit, Y Leonis is completely normal. The discussion of TW Andromedæ, on the basis of measures by Miss Davis of plates made with the 60-inch reflector by Mr. Shapley, is nearly ready for publication. Both photographic and photovisual magnitude-curves have been derived, which determines the color-index for all phases of the light variation. The computations show that at intervals of 4.12 days one star (with 50 times the volume of the sun) totally eclipses its companion, which is nine times as bright but of only one-half the radius.

One of the subclasses of the faint cluster-type variables in the globular system Messier 5 is distinguished by extremely short periods of light variation (4 to 8 hours) and nearly symmetrical magnitude curves. A number of important points connected with the problem of stellar variation are involved in the detailed study of these variables which now is under way. At the same time, the constancy of the light for the supposedly invariable stars of this cluster is under investigation. Special series of photographic and photovisual plates have been measured and reduced by Mr. Shapley, Miss Davis, and Miss Ritchie. It is expected that the research will be completed during the present year.

On Mr. Shapley's recent photographs of clusters, Miss Ritchie has found 98 new variable stars, as follows:

N. G. C. 4590	= Messier 68	28
5024	53	22
6864	75	13
6981	72	30
7492	..	5

A series of plates has been secured for a detailed study of the variables in the faint and distant cluster N. G. C. 6981.

STELLAR SPECTROSCOPY.

The stellar spectroscopic work throughout the year has been carried on by Mr. Adams, Mr. Joy, and Mr. Strömberg. Mr. Merrill, Mr. Sanford, and Mr. Duncan shared in the observations during the summer of 1919. A considerable portion of the work had been planned with a view to facilitating the determination of the absolute magnitudes of the highly luminous stars by the spectroscopic method. For this purpose a large number of stars with apparent visual magnitudes of 5.0 or brighter have been added to the observing list. Such stars furnish material especially suitable for a comparison with results from mean parallaxes obtained from parallactic motion. Spectrographic observations have also been continued on the stars listed in the American Ephemeris and the selected groups of stars to which reference was made in the last annual report.

The number of photographs of spectra obtained during the year with the Cassegrain spectrograph and the 60-inch reflector is 1,337. These are distributed in magnitude as follows:

Brighter than 5.0 visually	480
5.0 to 6.0	408
6.0 to 7.0	252
7.0 to 8.0	119
Fainter than 8.0	78

The 7-inch camera has been used for 90 of the spectrograms of the fainter stars. The observations include 20 photographs of Nova Aquilæ No. 3 and 100 photographs of variable stars.

Radial Velocities.

The radial velocities of 133 stars have been determined from measurements of three or more spectrograms. Among the more interesting results for individual stars the following may be mentioned:

(1) The orbits of four spectroscopic binaries have been published. These are Boss 593, Boss 2285, W Ursæ Majoris, and Z Herculis. In the case of the last two stars the presence of the spectra of both components and the photometric data provide the means for a determination of the absolute dimensions of the orbits.

(2) A list of 14 spectroscopic binaries was published early in the year. Five of these stars show composite spectra.

(3) An investigation of the motions in space of 37 stars with radial velocities exceeding 80 km. leads to the conclusion that stream-motion is very marked for these stars.

(4) The apices of these stars lie almost wholly in one hemisphere, their galactic longitudes all falling between 131° and 322°.

(5) The components of velocity parallel to the plane of the Galaxy are more than double that normal to this plane. The velocity of the centroid of these stars is remarkably high, amounting to 74 km., even

when stars with total velocities exceeding 300 km. are omitted from the computation. The motion of the centroid is almost exactly parallel to the plane of the Galaxy.

(6) The direction of the major axis of the velocity-ellipsoid is in good agreement with that found from investigations by Strömberg and by Raymond on the motions of dwarf stars.

(7) If the stars are divided into groups having average magnitudes greater and less than 3.0, it becomes clear that the fainter stars are moving much more rapidly than the brighter stars, and that the apices of their motions lie much more nearly in the plane of the Galaxy.

(8) The stars with the largest velocities in space are of type F, and among these the earlier types have the larger values. Thus, the stars of types F0 to F5 have an average space-motion of 365 km.; those of type F in general, 307 km.; those of type G, 156 km. Of the entire list of 37 stars, 26 are of types F and G.

Spectroscopic Determinations of Luminosity and Parallax.

The extensive investigation referred to in the last annual report, having as an object the computation of the systematic corrections to be applied to the absolute magnitudes derived spectroscopically from the original curves of reduction, has been nearly completed. The method employed has been to compute the mean absolute magnitudes of groups of stars with but a small range in spectral type and line-intensity, using for this purpose the parallaxes measured trigonometrically, the parallactic motions, and the peculiar motions. The three methods give results in good agreement with one another, although, of course, the degree of accuracy is quite different for stars of different distances and velocities. The mean absolute magnitudes derived in this way are then compared with the absolute magnitudes derived spectroscopically. Three general conclusions may be drawn from this comparison:

(1) The spectroscopic criteria of absolute magnitude are valid for the stars of highest luminosity, a regular change in absolute magnitude accompanying a change in the intensity of the selected lines.

(2) The previous reduction-scale employed for the determination of absolute magnitudes obtained by the spectroscopic method gives values which are nearly correct in the case of the fainter stars but systematically too faint in the case of the brighter stars. The correction required is of the order of -0.5 to -1.0 magnitude.

(3) The probable error of the absolute magnitude of a single star as derived by the spectroscopic method varies with the spectral type from about ± 0.1 for the early F-type stars to ± 0.6 for the later K-type.

As a result largely of this investigation, it now becomes possible to establish what may be considered a definitive scale for the spectroscopic determination of absolute magnitudes. This has not been

possible hitherto, on account of the inadequate character of the existing parallax material upon which to base the reductions. The absolute magnitudes and parallaxes of about 1,800 stars have now been derived upon the revised system and will soon be ready for publication.

As a by-product of the investigation of mean parallaxes and mean proper motions, reference may be made to the fact that the mean parallax derived spectroscopically for groups of stars of definite apparent magnitude does not become zero when the proper motion becomes vanishingly small, but tends toward a finite limit. A study of this deviation from Kapteyn's formula shows that this peculiarity is a necessary consequence of the grouping according to proper motion, and of the fact that there is a definite upper limit to the luminosity of a star.

STARS WITH SPECTRA CHARACTERISTIC OF THE CEPHEID VARIABLES.

In the course of the classification of stellar spectra, 18 stars have been found with spectra very similar to those of the Cepheid variables. They are characterized by very strong hydrogen lines and enhanced lines which are several times as intense as in normal stars of the type to which these stars belong. Many of the spectra are essentially identical with that of typical Cepheids such as δ Cephei and ζ Geminorum, and it seems clear that the relationship to the Cepheids must be intimate, although no variation of light is known with certainty in any case.

An examination of the list shows that these stars resemble the Cepheids in the following respects as well: (1) very small proper motion; (2) low galactic latitude; (3) small radial velocity; (4) very high intrinsic luminosity. At least 6 of the stars show a small variation in radial velocity.

It seems probable that a further study of the spectra of such stars may aid in the solution of the problem of Cepheid variation.

THE SPECTRUM OF NOVA AQUILÆ NO. 3.

Photographs of the spectrum of Nova Aquilæ have been made regularly throughout the year. In addition to the usual changes characteristic of Novæ, the spectrum has shown remarkable peculiarities, especially in the form and structure of the emission bands. Some of the more important results of detailed study of the photographs are briefly:

(1) A large number of absorption lines identified in the spectrum of Nova Aquilæ have also been identified in that of Nova Geminorum No. 2. Their displacements are almost exactly one-half as great as in Nova Aquilæ.

(2) The displacements of the two components of the hydrogen and helium lines in Nova Aquilæ are in the ratio of 3 to 2. A comparison with the three other principal Novæ of recent years, Nova Aurigæ of

1892, Nova Persei of 1901, and Nova Geminorum of 1912, is shown in the accompanying table:

Displacement at λ 4500.

	H lines (1st comp.).	H lines (2d comp.) and metallic lines.
Nova Aquilæ.....	−33.8	−23.1
Nova Persei......	....	−22.9
Nova Geminorum.	−21.6	−11.5
Nova Aurigæ.....	....	−11.4

Within the limits of error of measurement, accordingly, the displacements in all of these stars are in the ratio 3 to 2 to 1.

(3) The displacements of the absorption lines in the spectrum of Nova Aquilæ showed a rapid decrease immediately after the discovery of the star and then a gradual increase of about 0.5 A each day until a maximum was reached late in June 1918. After this there seems to have been a slow decrease as the lines grew faint and disappeared. It seems probable that a similar change occurred in the other Novæ to which reference has been made, so that the relationship of the displacements referred to above held strictly for the same spectral phase. Measurements of the photographs of the spectrum taken on June 8 and 9, 1918, immediately after the discovery of the star, show that the minimum negative displacement coincided with the maximum of light.

(4) The structure of the emission bands during the autumn of 1918 and the spring of 1919 appears to have been the same for both hydrogen and nebulium and apparently was of a fairly stable nature. The bright maxima and the absorption lines are in all cases displaced from the centers of the bands by amounts which are proportional to the wave-length.

MISCELLANEOUS INVESTIGATIONS.

(1) Observations of the spectrum of the variable star RU Camelopardalis show that it belongs to type R, but has bright hydrogen lines at minimum of light and dark hydrogen lines at maximum. The enhanced lines are strong and the character of the general spectrum is very similar to that of the Cepheid variables, among which the star is usually classed. The radial velocity is variable, with a range of about 45 km., the maximum velocity of approach coinciding with maximum of light, as in the case of the Cepheids. The relative intensities of the bright hydrogen lines are the reverse of those found among variables of type Md.

(2) The Cepheid variable W Serpentis has been found to have bright hydrogen lines with a dark central component symmetrically placed. This is the first variable of this type known to show bright lines in its spectrum.

(3) Two eighth-magnitude stars, Lalande 23995 and Lalande 27274, have been found to have radial velocities of +144 and +159 km. respectively.

(4) Preliminary reductions indicate a double amplitude of variation of about 60 km. in the radial velocity of the variable star X Cygni.

(5) Photographs secured with a small spectrograph at the primary focus of the 60-inch reflector indicate that the Harvard Variable 3435, with a period of $3^h\ 52^m$, is a spectroscopic binary with a relatively small amplitude of variation in velocity. Similar photographs of the spectrum of T Tauri show no variation from that obtained 3.5 years previously, and that the radial velocity is apparently constant.

(6) A further investigation has been made of the more refrangible region of the continuous spectrum of stars. About 900 spectrograms have been used and the results confirm the conclusion that for a given spectral type the violet portion of the spectrum is stronger in the intrinsically faint stars than in the highly luminous stars. The difference is more pronounced in the more advanced spectral types. The extensive material has made possible the elimination and correction of some of the factors which previously have led to uncertainty.

(7) An investigation of the radial velocities and spectral characteristics of stars of type Md has been commenced with the 60-inch and 100-inch reflectors. At present 14 stars have been observed, for 12 of which no observations with slit spectrographs had been made previously.

(8) Experiments have been made with the 10-inch refractor and an objective prism to test the possibilities of this instrument for observing stellar spectra in the red and infra-red. A number of photographs of M-type stars show the strong titanium-oxide bands in the red plainly, and the atmospheric line A has been recorded in the spectra of some other stars. The steep color curve of the lens, however, permits only a very short section of spectrum to be photographed in good focus at one time. Accordingly, a problem to which the instrument is much better adapted is now being undertaken. This is the observation of the *Hα* line in the spectra of stars of type B. It seems probable that in view of the great variation in the character of this line, which passes through all the stages from a prominent absorption to a strong emission line, a classification of B-type stars based upon its appearance will be of considerable value. Two new stars with *Hα* bright have already been found in this way.

Spectroscopy of Nebulæ and Star-Clusters.

Observations on the spectra of certain nebulæ and star-clusters have been made by Mr. Sanford with the small slit spectrograph at the primary focus of the 60-inch reflector. Among these is a photograph of the spectrum of the Crab Nebula made with an exposure time of 48 hours.

Although the negative is somewhat underexposed, it yields two interesting results:

(1) The nebula has a large negative velocity, of the order of −600 km. on the west side and −1,000 km. on the east side, at distances in each case of about 60″ from the nucleus.

(2) The doubling of the nebular lines first observed by Slipher seems to be fully confirmed. The separations for the lines λ3728 and λ5007 are 29 and 41 A, respectively, values which indicate a direct proportionality between separation and wave-length.

Determinations of radial velocity have been made for the following star-clusters:

Messier No.	N. G. C. No.	Radial velocity.		Exposure time.	Objects measured.
		Sanford.	Slipher.		
		km.	*km.*		
53	5024	−200	−175	16^h30^m	Nucleus.
3	5272	−140	−125	20 6	Four stars north of nucleus, Von Zeipel's Nos. 612, 752, 1127, 1208; 37 absorption lines measured.
12	6218	+160	....	9 55	Four stars near nucleus.
....	6709	+ 15	....	5 10	Late B-type star, of which Barnard says, "does not present hard disk like other stars."

PHYSICAL LABORATORY.

INSTRUMENTS.

The chief additions to the equipment of the Physical Laboratory have been a short-focus plane-grating spectrograph, designed by Mr. Anderson; a small electric furnace, designed by Mr. King for use between the poles of the large Weiss magnet; a Langmuir high-vacuum pump with auxiliary pump; and speculum-metal mirrors and other accessories for the interferometer spectrograph.

The short-focus plane-grating spectrograph, designed especially for the study of faint light-sources, has for collimating lens a Brashear doublet of 5 inches aperture and 60 inches focal length, and for camera lens a Bausch and Lomb Tessar Ic of 3.5 inches aperture and 15.75 inches focal length. The 4-inch Rowland plane grating is used at a constant angle with the axis of the camera lens. When this angle, as is usually the case, is about 70°, the dispersion is nearly three times as great as it would be with a nearly normal spectrum. The camera, with the grating, is capable of rotation about a vertical axis through the grating, the range being about 30°. The collimator can also be rotated in the same way through an arc of 90°, which makes it possible to use any order of spectrum up to the fourth. The plate-holder takes plates 2.5 by 4 inches and is so mounted that, in addition to the focusing adjustment, it can be tilted, and also given a vertical motion, in order to place several exposures on the same plate. In the

third order, a 4-inch plate covers a little less than 400 A, corresponding to an average dispersion of about 4 A per millimeter.

Our knowledge of the Zeeman effect has been obtained chiefly through a study of spark spectra, produced between the pole-tips of large electro-magnets, where the uniform field is so limited that only small sources, such as sparks or vacuum tubes, can be used. It is becoming more and more necessary to study the spectra of other sources in a strong magnetic field, especially that of the electric furnace. This requires a fairly uniform magnetic field of high strength throughout a space at least 2 inches in diameter by 4 inches in length. Mr. Anderson's calculations show that for a water-cooled solenoid without any iron approximately 400 k. w. are required to give a field of 45,000 gausses in such a space, and that for fields of this size and intensity there is little or no advantage in the use of iron. A 500 k.w. motor-generator set has accordingly been ordered, to furnish about 4,000 amperes direct current at 125 volts. An underground tank having a capacity of about 5,000 cubic feet will be constructed to hold the water necessary for cooling purposes. Solenoids of various sizes to suit different purposes will be constructed as needed, as the amount of copper required for a single solenoid is very small, ranging from 10 to 50 pounds. When this apparatus is installed the laboratory will have exceptional facilities for the study of the Zeeman effect, so necessary in the interpretation of sun-spot spectra. It is also hoped that the study of arc spectra with very heavy currents may lead to interesting results.

In order to make the interferometer spectrograph available for observations in the ultra-violet, three new speculum mirrors have been ground and figured in the optical shop. One of these, 6 inches in diameter and 21 feet radius of curvature, is used as a collimator in the auxiliary spectrograph; a 2-inch mirror of 50 inches radius of curvature is used for projecting the interference pattern upon the spectrograph slit, while the third mirror, 6 inches diameter and 48 inches radius of curvature, is for projecting an image of the source upon the etalon.

A new film-holder receiving a film about 16 inches long, has been made in the shop for use with the interferometer spectrograph. It is adjusted to the focal curve of the grating so as to bring 2,000 A into good focus in the first-order spectrum. This permits a much greater number of standards to be observed upon each photograph, thus increasing the accuracy attainable in the relative values of the wave-lengths.

ELECTRIC-FURNACE INVESTIGATIONS.

The following lines of work with the electric furnace were pursued during the year by Mr. King, in part with the regular tube-furnace and in part with the special form constructed for use with the Weiss electro-magnet.

Infra-red Furnace Spectra.

Plates bathed with dicyanin were used in this investigation, the object of which was the extension into the infra-red of the data on the temperature behavior of spectral lines. Seventy-one spectrograms were made, the elements studied being iron, titanium, nickel, cobalt, barium, strontium, and calcium. The furnace spectra thus obtained extended to about $\lambda 9200$. Within this limit, a large proportion of the lines observed in the arc were regularly obtained with the furnace, together with fainter arc-lines which the furnace produces with relatively high intensity. Spectra were photographed at three temperatures and for the most part with two different spectrographs. The lines were classified according to the temperature at which they appear and the rate of increase of intensity with temperature, in the same way as in previous work. The low-temperature lines thus segregated will be of interest when a more extended study of stellar and sun-spot spectra for this region has been made. The high-temperature lines, weak or absent in the furnace spectrum, are also important. Among these are the three strongest lines in this region of the solar spectrum. They belong to calcium and are strongly enhanced lines. The temperature classification is also proving useful in the selection of series lines in the case of barium and strontium.

Absorption Spectra with the Electric Furnace.

A graphite plug placed in the central portion of the furnace-tube gives an incandescent background for the radiating vapor and produces an absorption spectrum which may be examined at the same temperatures as are employed for emission spectra when the plug is not used. Many interesting features appear in the 54 spectrograms thus far made, chiefly of iron and titanium. A pure absorption spectrum is observed, no emission lines or bands appearing, thus indicating that the radiation of a black body, which the plugged tube closely approximates, is stronger than that of a vapor when excited by the same degree of temperature. Furthermore, striking differences appear between the absorption spectrum and the emission spectrum which can be photographed at the same temperature by removing the plug. For a given temperature, the absorption lines are fewer in number than the emission lines, and the absorption lines which do appear are those of the emission spectrum at a much lower temperature. Thus a temperature which produces a rich emission spectrum gives in absorption only the low-temperature lines. As the temperature is raised, other groups appear, which belong to successively higher temperature classes. The method gives a close measure of the absorptive power of each spectrum line, and the grouping arranged on this basis is found to be in complete agreement with the temperature classification already

made. Thus the low-temperature lines are the more strongly absorbing, which is in harmony with the phenomena of reversal. The present experiments, however, show the relation with especial clearness, since the emission spectrum proves that at a certain temperature the line is being radiated but that a higher temperature is required before it can be absorbed. The change of absorptive power with wave-length is very decided, the effect increasing rapidly toward shorter waves.

The Zeeman Effect for Electric-Furnace Spectra.

The use of a small tube-furnace in a magnetic field opens an extensive line of investigation, of which a preliminary survey has been made. A graphite tube 4 inches long, inclosed in a water-cooled jacket, was placed axially between the poles of the large magnet, which, with this gap, gave a field of about 6,500 gausses. The tube, of which 3 inches were heated by a strong alternating current, readily gave the n-components of the furnace lines, when observed along the lines of force. The spectra observed were of iron, from $\lambda 3500$ to $\lambda 6700$, and of vanadium, from $\lambda 5100$ to $\lambda 6700$. Comparing the Zeeman components in furnace and spark spectra, the lines common to both showed no difference, either in character or magnitude of the separations, so that in future work the two sources can be used to supplement each other, to obtain in the magnetic field the lines most favorably given by each. A large class of the lines, however, which, probably without exception, are intensified in sun-spot spectra, are much stronger in the furnace than in either arc or spark, so that the exposure time for such lines in the magnetic field is a matter of minutes with the furnace and of many hours with the spark. Even in the limited work thus far done, the furnace has given the magnetic separation of a considerable number of lines not yet obtained with the spark. High fields are not possible with the present apparatus, but the use of the furnace inside a solenoid will remove this limitation, and the characteristic sharpness of furnace lines will be of much advantage in defining the Zeeman components when the furnace is inclosed in a vacuum chamber.

Another important advantage of the furnace in the magnetic field is the ease with which the inverse Zeeman effect is produced by using a plug in the tube to give an absorption spectrum, as described above. A number of spectrograms have been made with this arrangement. The n-components appear to be quite the same in absorption as in emission. The study of absorption phenomena at varying angles to the lines of force with optical apparatus similar to that used in solar work may, however, give data on the inverse effect which will be directly applicable to sun-spot phenomena. In any case, the magnetic action on absorption lines can now be studied with the same facility as for emission lines.

Miscellaneous Experiments with the Furnace.

About 30 electric-furnace spectrograms have been made for purposes not already mentioned. These included supplementary photographs of the spectra of manganese, iron, and chromium; a series for the cerium spectrum at various temperatures; a series for iron, copper, and silver at atmospheric pressure for comparison with vacuum spectra in connection with questions as to the character of the furnace radiation; and several photographs of barium and strontium for the measurement of lines which are sharper in the vacuum furnace than in other sources and important in the evaluation of series constants.

A detailed comparison of electric-furnace material with that for sun-spot spectra has been made, but is as yet incomplete, some points requiring more observational data. The relation indicated in the early work, namely, that low-temperature lines are strengthened and high-temperature lines weakened in sun-spots has been found to be very general, the more pronounced cases of strengthened spot-lines being those appearing with especial strength in the furnace as compared with the arc or spark. Various differences of detail were found for different elements. In the spectra of titanium and vanadium, a large number of lines which are fairly strong in the furnace agree closely with sun-spot lines which are faint in the solar spectrum and unidentified by Rowland. Their origin seems thus to be established, and the furnace can be employed for any detailed study of such lines that seems desirable.

SECONDARY STANDARDS OF WAVE-LENGTH.

The redetermination of secondary standards of wave-length in the iron-arc spectrum by Mr. Babcock and Mr. St. John is now nearly complete over the region λλ 3370–6750, in so far as the interferometer program is concerned. During recent months about 30 plates have been taken for this purpose, covering the region λλ 5400–7300; 18 of these, including the best photographs, have been measured and reductions are nearly complete. Numerous iron lines, in addition to the international secondary standards, were observed, and several of the plates contain spectra of barium, strontium, or calcium from a vacuum arc as well as the iron standards, thus making available many excellent tertiary standards at the same time.

Because of numerous extensions into the infra-red of spectroscopic work now in progress, and the present lack of secondary standards beyond λ 6750, the program includes the establishment of reliable new standards free from pole effect over the region which can profitably be observed with the aid of dicyanin. It is likewise highly important to determine many new standards in the ultra-violet region, as the adopted list of secondary standards terminates at λ 3371. As noted elsewhere, the interference apparatus is being arranged for opera-

tion in the ultra-violet, as far as the reflecting power of speculum metal permits.

On lines free from pole effect the measured wave-lengths are in good agreement with those of other recent observers, except in a few cases where differences as large as 0.002 A are found. Special attention is given to all such cases, and in addition the relative values of a large number of lines are being separately determined under the direction of Mr. St. John by means of the plane grating. It is thought that in this way the inclusion of any errors, except those necessarily involved in the methods of observation, may be avoided.

WAVE-LENGTHS IN MIXED ARCS. PRESSURE EFFECT.

Mr. Babcock has found it feasible to extend to interference observations the method of simultaneous exposures to two sources of light, which has proved so powerful an aid in previous work with the plane-grating spectrograph. A number of very satisfactory photographs have been secured, upon which occur secondary standards from the iron arc, intermingled with lines from barium, strontium, calcium, or cadmium, taken simultaneously from a vacuum arc through the same interferometer. Two or more of these elements may often be used in the same vacuum arc, and as many of their lines are very intense as well as sharp, they serve as excellent standards of wave-length. It has accordingly been easy to apply this method to an examination of the question sometimes raised as to the constancy of arc wave-lengths in mixed arcs, *i.e.*, arcs containing more than one element. For example, simultaneous exposures were made to the interference spectra of the iron standards and to the strong red barium lines obtained from a pure barium salt upon carbon terminals in a vacuum chamber. Upon other photographs the combined spectra were recorded when the pure barium was replaced by a mixture of barium and strontium, barium and calcium, or barium and chromium, *i.e.*, barium chromate. In the case of every line so far examined, the wave-length is the same when the element is used alone as when two or more elements are mixed in the same arc. This method is now to be applied to other mixtures and to arcs having one or both terminals of metal, although until more definite and positive evidence is adduced in support of the supposed variation, it hardly seems necessary to devote much more time to it. It is, in fact, highly probable that pole effect in the arc is at the bottom of the phenomenon.

The method of simultaneous exposures with the interferometer also lends itself to the study of the pressure effect upon the spectrum. Experience has indicated the desirability of making such observations over a pressure range from zero to one or two atmospheres, in order not to introduce too much variation in the intrinsic width and sharpness of the spectral lines. This, with the careful elimination of pole

effect, is being undertaken both with the interferometer and with the grating. In fact, the value of the interferometer for studying small variations of wave-length in general is appreciably increased by this method of observation, inasmuch as the small uncertainties inherent in the procedure involving alternate exposures are eliminated.

NATURE OF POLE EFFECT.

A beginning has been made upon the minute examination of the structure of iron-arc lines which exhibit pole effect. For this purpose visual observations are being made by Mr. Babcock with the 33-plate Hilger echelon spectroscope upon two or three strong lines in the yellow and green, which have been found to show pole effects of opposite sign. When observed close to the negative pole of a Pfund arc carrying about 6 amperes, the lines $\lambda 5615$ and $\lambda 5383$, groups *d* and *e*, respectively, show evidence of structure. These observations are being extended by photographs of very high dispersion, using gratings of high resolving power, in the hope of deciding whether the structure is due to incipient reversal or to true complexity of the spectral lines. In this way additional information may be obtained as to the real nature of pole effect.

Mr. Merrill, who joined the Observatory staff in January, has made a study of the pole effect in several metallic arcs, especially that of nickel. Special attention was paid to the pole shift of lines known to be greatly affected in an electric field. These results were used by Mr. Takamine in his discussion of the Stark effect for nickel.

OBSERVATIONS OF ARC, TUBE-ARC, AND SPARK SPECTRA.

Observations of the relative intensities of lines in different portions of the arc have been made by Mr. Merrill. Numerous photographs were taken with the arc projected in such a way that its axis coincided with the slit. The strengthening at the positive pole was the leading feature observed. Grouping the lines according to the degree of strengthening at the positive pole gave a classification which, with certain interesting exceptions, runs parallel to the temperature classification developed during previous work at the Observatory. The appearance of enhanced lines at the positive pole of the arc corresponds with the furnace evidence that they indicate high temperature conditions. These observations of the arc spectrum have resulted in the classification of 541 lines of iron and 227 of cobalt according to the degree of strengthening at the positive pole. Some material for the nickel arc was also obtained.

Observations of the infra-red spectrum of the tube-arc have been made by Mr. King and Mr. Merrill. The carbon-spark lines are strong in this source and much sharper than the spark, thus permitting high accuracy of measurement; several new carbon-spark lines have

been identified. Numerous air-lines appeared in the infra-red, including the well-known oxygen triplet λ 7771–4.

Mr. Merrill has also studied the air-lines given by metallic sparks in the red and infra-red; 57 air-lines between λ 5927 and λ 8719 have been measured, of which 47 do not appear in previous lists. Lines of nitrogen, oxygen, hydrogen, and argon are present, those of oxygen including the important solar triplet at λ 7771–4, which is much enhanced in the spark and probably weakened in sun-spots as compared with the solar disk. 34 of the 57 lines remain unidentified, and further observations for this purpose are planned.

PRODUCTION OF METALLIC SPECTRA IN HIGH VACUA.

This work has been carried on jointly by Miss Carter and Mr. King, in continuation of the experiments conducted last year. The metal is vaporized at the focus of a beam of cathode rays in a high vacuum and the spectrum of the vapor in the path of the rays is photographed. Observations of the spectra of manganese, titanium, iron, magnesium, calcium, and cadmium have yielded extensive lists of lines for each, the relative intensities being quite different from those of other sources. Leading features are the intensification of certain line series and the production of enhanced lines to different degrees with different elements. Little change appeared, whether the target of the cathode rays was used as anode or insulated. This fact, and some resemblances to the spectrum near metallic cathodes, indicate that the concentration of the cathode stream at the distant target resulted in a transfer to this point of conditions which can be obtained at the cathode itself by proper arrangements. The experiments now in progress appear to confirm this. Strong spectra at both anode and cathode are obtained, which differ greatly in character and promise to throw much light on the causes of pole-effect phenomena, since the radiation processes in vacuum-tubes are subject to more definite interpretation than those taking place in the arc.

INVESTIGATIONS OF THE STARK EFFECT.

In September 1918, Mr. T. Takamine, of the Tokyo Imperial University, began an investigation of the Stark effect, using the apparatus employed by Mr. Anderson in 1916–17. The region from λ 3600 to λ 5700 was covered for most of the ordinary metals, with field-strengths occasionally as high as 60,000 volts per centimeter. The results may be briefly summarized as follows:

(1) Lines in the spectra of the following elements were found to be affected by an electric field: Ag, Au, Co, Cu, Fe, Mg, Mo, Na, N, and O.

(2) Close relations were found between the pole effect and the Stark effect in the spectra of iron and nickel.

(3) Several instances showing the close relation between the Stark effect and the broadening of lines in arc and spark spectra were observed.

(4) In the spectra of copper and silver a number of detached components and isolated lines close to the series lines were found, which have the peculiar property of showing themselves only in a strong electric field.

In March 1919, the grating spectrograph used for the Stark effect by Mr. Anderson and by Mr. Takamine was taken down in order to have the optical parts fitted into a new metal mounting constructed in the machine-shop. While this was being done, Mr. Anderson studied the Stark effect in the region λ 2200–λ 3600, using the large Fuess quartz spectrograph, the prism of which was refigured in order to improve the definition. About 60 spectrograms were obtained with this instrument for the metals already studied in the visible region by Anderson and Takamine. In most of this work rectified alternating current from a small high-potential transformer was used instead of direct current from the set of dynamos, as this was found easier to work with, and equally effective.

The new metal mounting for the grating spectrograph was delivered by the machine-shop about the middle of August, and as soon as data for all of its adjustments are obtained a careful study of some of the peculiar Stark effects observed, especially for chromium, will be undertaken.

CONSTRUCTION DIVISION.

DRAFTING AND DESIGN.

The drafting department has been occupied mainly with the 100-inch telescope and with work undertaken for the Signal Corps and the Ordnance Department of the Army in connection with the war.

New designs for the 100-inch telescope include compression rings for the Newtonian and focal-plane cages required to give the cages greater rigidity, revisions for the main observing platform and the mirror elevator, an observing platform for use at the Cassegrain focus numerous small parts and attachments, and a number of cases used for housing equipment when not in use.

The work done for the Signal Corps was experimental in character, and such as to require many special drawings. For the Ordnance Department designs were made for 13 machines used in the optical work which was carried out under the direction of the Observatory.

THE OPTICAL SHOP.

Prior to April 1, the work of the Optical Shop was entirely devoted to the requirements of the Ordnance Department of the Army, as described in a separate report on the war service of the Observatory. Since that date, the following optical parts have been figured: 17 plane and

concave speculum metal mirrors, ranging in diameter from 4 to 10 inches, for grating plates and other purposes; two 6-inch test planes; two right-angle prisms. Two quartz prisms and one glass prism have also been refigured, and much miscellaneous optical work has been done.

THE INSTRUMENT SHOP.

Prior to the armistice, the instrument shop (Mr. Ayers, foreman; Mr. Jacomini, chief instrument maker) was almost exclusively engaged with Government work, as detailed in a separate report on the war services of the Observatory. In fact, including overtime, 57 per cent of the shop-work during the year was for the Bureau of Standards, the Signal Corps, the Ordnance Department of the Army, and the Navy Department.

Since the armisitice, excepting for the completion of the optical work carried through until April at the request of the Ordnance Department, the instrument shop has been engaged on the regular work of the Observatory. That chargeable to the Hooker telescope includes work on the Cassegrain spectrograph, double-slide plate-holder, tube-balancing system, coudé mechanism, cage-clamps, mirror temperature-control, mirror-silvering equipment, Newtonian and Cassegrain cages and mirror mountings, driving-clock, sidereal indicator, burnishing apparatus, observing platform, dome ladders and stairs, and dark-room equipment. The other chief items of construction relate to the cœlostat and spectrograph of the Snow telescope, a focal plane spectrograph, stellar comparator, laboratory grating spectrograph, Smithsonian Observatory equipment, and instrument and building repairs.

RULING MACHINE.

The work on the ruling machine during the early part of the present year revealed the fact that the spacing wheel (a steel forging) had warped somewhat since it was first made. The tedious work of correcting this occupied Mr. Jacomini some three months, but was perfectly successful. Cross-ruling tests were then made which conclusively showed the machine free from periodic errors. There were, however, accidental errors of rather large amount. After a lengthy process of elimination their cause was found in the casting supporting one pair of the ruling-carriage ways. This casting has now been strengthened and supported in such a way that it is hoped no further difficulty will occur. These changes, however, necessitated a regrinding of the ways in order to make them again straight and parallel. This work is now nearly completed.

ONE-HUNDRED-INCH HOOKER TELESCOPE.

The 100-inch Hooker telescope, though greatly delayed by the war, is now in regular use. It will therefore be of interest to give some

details of the tests already applied, which leave no doubt that this powerful addition to the equipment of the Observatory will permit our observational program to be greatly extended.

In the preliminary tests of the Hooker telescope, mentioned in the last annual report, the star images at the 134-foot focus were imperfect, and the driving-clock was found to have a small periodic error of very short period, visible when the guiding-star was observed on the cross-wires with powers higher than 1,000. This error was traced to a slight springing of one of the shafts in the clock-train, and was practically eliminated by introducing an additional bearing. The source of the defective star images was somewhat obscure, but persistent work on the part of Mr. Pease has disentangled the several elements involved. These were three in number: (1) imperfect adjustment of the edge-support of the 100-inch mirror; (2) occasional effects of coma and flare due to atmospheric disturbances near the telescope, especially the escape of warm air from the space behind the large mirror when the cooling coils were not in operation; and (3) occasional atmospheric disturbances, visible also with the 60-inch telescope, which produce an effect on the star images closely resembling such astigmatism as might result from distortion of the large mirror.

The edge-support was adjusted by relining the edge arcs and bringing their pressure to bear exactly in the correct plane. Flare was eliminated by circulating water of the right temperature through the coils provided for this purpose behind the mirror and encircling its edge. Water pumped from tanks within the telescope pier was temporarily employed, and a complete automatic control system, to maintain the mirror throughout the day and night at any desired temperature, is now being installed. The astigmatic effect sometimes resulting from the atmosphere will be felt only in direct photography of star-fields at the 134-foot focus, but the excellent images photographed on many occasions even with this great focal length show that no apprehension need be felt as to the practical performance of the telescope, which greatly surpasses the 60-inch reflector in every class of work.

Up to the present time, most of the observations have been made with the Cassegrain combination of mirrors giving an equivalent focal length of 134 feet. The focal plane of this combination, which involves three reflections of light, is at a point on one side of the tube about 11 feet from its lower extremity. The attachments available for use at this point include a large double-slide plate-holder; a stellar spectrograph,[1] for use with one, two, or three prisms, having a collimator of 40 inches focal length and several cameras; and a small spectrograph, usually employed without slit, provided with a collimator of 18 inches focal length, a single 39° prism, and a camera of

[1] Equipped by Mr. Babcock with a new form of thermostat.

3 inches focal length. The latter instrument can be mounted on the double-slide plate-holder, which can thus be used for guiding during exposures.

In order to determine precisely what advantages may be expected from the use of the 100-inch telescope, it has been submitted to a comparative test with the 60-inch telescope, the qualities of which are known from long experience. When feasible, the observations required for such tests are made simultaneously with the two telescopes, which are not far apart on Mount Wilson, and are therefore subject to the same atmospheric conditions. In the case of an instrument of the great aperture and equivalent focal length of the Hooker telescope, when used at the 134-foot focus, the chief outstanding question, after the rigorous optical and mechanical requirements have been met, is the quality of the atmosphere. In stellar spectroscopy the problem is whether the star images, at the 134-foot focus, will be so small as to permit essentially all of the light to pass through the slit during the exposure. If this can be accomplished, the Hooker telescope should give about 2.8 times as much light as the 60-inch telescope, thus rendering possible the observation of stars about one magnitude fainter than those within the reach of the latter instrument.

To answer this question, a comparative simultaneous test was made on the evening of August 13, 1919. The spectrum of the star ϵ Andromedæ was photographed on Seed 30 plates from the same box with the two telescopes, using spectrographs having nearly identical optical constants, mounted at the Cassegrain focus.[1] For the 60-inch the equivalent focal length at this point is 80 feet, while for the 100-inch, as already remarked, it is 134 feet. Both spectrographs have collimators of 2.5 inches aperture and 40 inches focal length, and cameras of 4 inches aperture and 18 inches focal length. In each case a single 63° prism of 0.102 Jena glass is used, giving a dispersion of 36 A to the millimeter with the camera employed. The slit-widths of the two spectrographs were varied until the photographic resolution, determined by comparing close pairs of lines in the spectra of the same star, was found to be the same. The exposures on ϵ Andromedæ were made by Mr. Strömberg with the 60-inch and by Mr. Merrill with the 100-inch, under good conditions of seeing, and the plates were afterwards developed together.

Thirty-three spectrograms were secured for comparison. From 20 of these Mr. Strömberg finds the following mean ratios of exposure-times required to give the same intensities and photographic resolution with the two instruments:

Region..............	λ4000	λ4300	λ4500
Mean ratio..........	4.5	3.2	3.3

[1] The spectrograph of the 60-inch telescope contains a single plane mirror, not duplicated in the spectrograph of the 100-inch telescope.

As the light undergoes three reflections in each telescope, and as the small mirrors cut out nearly the same proportion of light in both cases, the theoretical ratio of light-gathering power would be $(\frac{100}{60})^2 = 2.78$. The presence of the plane mirror in the optical train of the spectrograph of the 60-inch telescope, and the fact that the three mirrors of the 100-inch telescope have been more recently silvered than those of the 60-inch, probably accounts in part for the comparatively high value of the ratio at λ 4000 (4.5), as the comparison spectra show no such change of relative intensity with wave-length. But these differences can not affect the brightness at λ 4500 by more than 15 per cent, judging from the constancy of the exposure-times for stars of a given magnitude required with the 60-inch throughout the dry summer season. Another comparison will be made after the mirrors of the 60-inch have been resilvered.

A second comparative test, not based upon simultaneous exposures, is afforded by Mr. Merrill's experience with stars of class Md. 201 of these interesting objects, brighter than magnitude 9.0 at maximum, are known north of $-30°$. With the 60-inch nearly all of these stars can be observed for the bright lines with exposures not exceeding 2 hours. For the great majority, however, exposures of 5 hours or more are required with this telescope to yield a measurable absorption spectrum with the spectrograph already mentioned. In fact, so few stars can be effectively observed for both dark and bright lines that it would be hardly advisable to enter upon an extensive study of these objects with the 60-inch.

The greater light-gathering power of the 100-inch, however, renders such a study perfectly feasible. With this telescope, using the spectrograph mentioned above at the 134-foot Cassegrain focus, Mr. Merrill has obtained good photographs of the absorption spectrum of RY Herculis, visual magnitude 8.8, in 2 hours, and of brighter stars of the same class with shorter exposures. Mr. Joy has experienced an equal advantage over the 60-inch in photographing the spectra of stars of other types.

Mr. Shapley, who is continuing his investigation of star-clusters with the 100-inch telescope, finds a similar gain of about one magnitude. With the small slitless spectrograph mounted on the double-slide plate-holder at the 134-foot focus of the 100-inch, the exposure-times for stars in the globular cluster Messier 11 are about as follows:

Photographic magnitude, 12; Exposure, 5 minutes.
" " 13; " 15 "

A further advantage results from the great scale of the clusters in this focus of the 100-inch, which permits the spectra of closer stars to be photographed separately.

Mr. Pease has obtained some excellent direct photographs of the stars in the central part of the globular cluster Messier 13 at the

134-foot focus, but on account of the pressure of other work it has not yet been feasible to make simultaneous exposures on the same cluster with the 60-inch under good conditions of seeing. The large scale of the Hooker photographs will permit the magnitudes of stars in the central parts of clusters to be determined with less disturbance from the Eberhard effect than has been experienced with the 60-inch. Simultaneous cluster photographs made with the two telescopes when the seeing was very poor (1 on a scale of 10) show decidedly better results for the 60-inch, as would of course be expected from its much shorter focal length.

Photographs of the moon have been made at the 134-foot focus of the Hooker telescope by Mr. Pease, with very satisfactory results. Many of these appear to be decidedly superior in definition to any previously taken with other instruments. The extraordinarily minute structure seen visually on many occasions indicates that under the best atmospheric conditions still better photographs can probably be obtained.

Some interesting photographs of Campbell's star with hydrogen atmosphere (B D + 30°3639), showing a curious rift in the atmosphere on one side, have also been made by Mr. Pease at the 134-foot focus, as well as several photographs of very small planetary nebulæ showing minute details of structure. Mr. Pease's photographs of Campbell's star with a slitless spectrograph seem to show that it is an annular nebula.

Some interesting experiments by Mr. Shapley and Mr. Benioff at the 134-foot focus of the Hooker telescope indicate important possibilities in photographing very faint stars. By placing a lens immediately in front of the photographic plate in such a way as to make the rays more rapidly convergent, thus bringing the equivalent focal length down to about 30 feet, stars have been photographed which are about 2.5 magnitudes fainter than those obtained during an equal exposure without the lens. Such a device is certain to have important applications, and it remains to be seen what a similar arrangement will accomplish at the principal focus of the Hooker telescope, where the star images will naturally be much smaller.

Some promising preliminary work (not using the lens just mentioned) has been done with improvised arrangements in the principal focus of the 100-inch mirror, but definitive tests at this point must await the completion of the Newtonian cage and the observing-platform, which will soon be ready for use.

CONSTRUCTION WORK ON MOUNT WILSON.

Most of the construction work of the year has been done in Pasadena, where a two-story building about 46 by 90 feet in size, together with a storehouse and furnace-room, were erected and equipped in connection

with the optical work done for the Army Ordnance Department. Mr. Jones also assisted in the erection of the barracks on the campus of Throop College of Technology for the use of the Students' Army Training Corps. On Mount Wilson, in addition to the work on the 100-inch telescope, a dwelling-house was erected for the use of Mr. Sherburne, night assistant, and much brush was cleared to decrease fire risks. The necessary building repairs, and the regular work of clearing and maintaining the mountain road, were also carried out under the direction of Mr. Jones, superintendent of building construction.

Mr. Dowd, engineer in charge of the Mount Wilson power-plant, has continued the electrical wiring in the dome of the 100-inch telescope, mounted and connected an anemometer at the summit of the dome of the 150-foot tower, installed a new circulating tank in the 150-foot tower telescope, wired the new spectrograph of the Snow telescope, and done wiring and made various repairs in connection with other instruments.

NUTRITION LABORATORY.*

FRANCIS G. BENEDICT, DIRECTOR.

Since the character of the special service in which the Nutrition Laboratory was engaged during the war required no fundamental alteration in the organization of the Laboratory, the signing of the armistice in November 1918 produced no change in the researches then in progress or in the other phases of laboratory activity. The Nutrition Laboratory is thus in a nearly normal condition, with its organization intact, although numerous changes among the younger members of the staff have taken place.

Special stress has been laid upon the technical details of the publication of two large reports, one giving the results of the study on the undernutrition of man, and the other a biometric analysis of human metabolism. The most extensive research carried out by the Laboratory since the last annual report—that on the undernutrition of beef animals—was a natural outcome of the study made in the winter of 1917-18 on the undernutrition of man. It was originally planned, at least in part, to supply information as to possible methods of conservation in time of national need. In view of the abstract scientific value of such a study, the research was continued after the signing of the armistice, even though the practical need for such data was apparently no longer imminent.

ADDITIONS TO EQUIPMENT.

Pursuit pendulum.—From the psychological data collected on aviation candidates at the Nutrition Laboratory in the spring of 1917, it was learned that certain tests of muscle coordination offered promise in the selection of aviators. The accuracy of ocular pursuit movements in following a swinging pendulum correlated fairly well with the subsequent progress of the men in learning to fly, but the photographic technique for recording such ocular pursuit movements appeared to certain individuals acting in an advisory capacity to the Government as too complex for adoption at the aviation fields. To meet this objection, Dr. W. R. Miles designed a simplified apparatus with which the eye-hand pursuit coordination can be accurately tested. In this apparatus a pendulum carrying a reservoir is arranged to swing over a sink or table, a small stream of water flowing from the reservoir as the pendulum swings. The individual under test attempts to collect the water in a cup of limited diameter. A separate cup is used for each double swing of the pendulum and the volume of liquid in each cup is measured. The test will be of general usefulness.

*Situated in Boston, Massachusetts.

Pursuit-meter apparatus.—Considerable time has been spent during the year in perfecting and rebuilding the pursuit-meter apparatus which was referred to in the last annual report under the title of "recorder for adequacy of motor adjustments."

Respiration chamber for large animals.—For use in the research on the undernutrition of beef animals, a large respiration chamber was constructed by the Laboratory mechanician, Mr. W. E. Collins, at the New Hampshire Agricultural Experiment Station in Durham. This animal respiration chamber is, in principle and general form, like the group respiration chamber referred to in an earlier report, but is smaller and is modified to meet the requirements of a research with such large animals as full-grown steers or horses. The inside chamber is 9 feet 7.5 inches long, 5 feet 5 inches wide, and 7 feet high, with the entrance at the back. The animal stands on a platform slightly inclined. This platform is movable, with the front end supported by chains and springs in such a manner that connection with a pneumograph and kymograph gives a graphic record of the movements of the animal. Accessory apparatus, similar to that used with the group respiration chamber, provides for the measurement of the carbon dioxid given off by the animals by the determination of the carbon dioxid in an aliquot sample of the ventilating air current.

COOPERATING AND VISITING INVESTIGATORS.

Dr. Elliott P. Joslin, who served as lieutenant-colonel in the Medical Corps in France during the war, has returned to this country and is now preparing for publication the results of his studies on metabolism in diabetes mellitus.

Dr. Fritz B. Talbot continued his cooperation in the studies of normal children up to the time of their completion on July 1, 1919, and is assisting in the preparation of the results for publication.

Dr. J. Arthur Harris attended to the major part of the details of proof-reading and oversight of the report on the biometric analysis of the results of metabolism studies in the Nutrition Laboratory, and has prepared several brief summaries of this analytical study.

Mrs. Cornelia Golay Benedict has continued her investigations into the calorific values of extra foods and has prepared a second report of her findings in this field of practical interest.

A large share of the success of the research with steers carried out at the New Hampshire Agricultural Experiment Station is due to the cooperation of Director J. C. Kendall and Professor E. G. Ritzman, whose scientific interest and attention to the details of the research have been unfailing.

An especially helpful feature of the research at the New Hampshire Agricultural Experiment Station has been the privilege of conference with Professor H. P. Armsby, of State College, Pennsylvania, who

visited the station in May 1919, inspected the animals and equipment, and advised as to methods of realimentation. His extensive experience in similar researches with animals made his counsel of special value.

STAFF NOTES.

After several years' most efficient service as chemist of the Laboratory, Miss Elizabeth B. Babcock resigned on May 1, 1919.

Following a number of years' service in the calorimetric work of the Laboratory, Mr. Louis E. Emmes found it necessary to resign for a permanent residence in the West, owing to illness in his family.

INVESTIGATIONS IN PROGRESS.

Distribution of alcohol in hens after exposure to alcohol-vapor.—A research on the distribution and concentration of ethyl alcohol in the tissue of hens after exposure to its vapor has been conducted by Dr. T. M. Carpenter, with the cooperation of Miss E. B. Babcock. The general procedure has been to place a hen in a chamber saturated with alcohol-vapor for a given period, to kill the hen immediately at the conclusion of the period, and to determine the alcohol in the various tissues by the Nicloux method. Graphic registration of the activity was secured and an attempt was made to determine the oxygen consumption during the period. As results obtained in the early part of the investigation indicated that the amount of alcohol remaining in the body bore some relation to activity, a number of the hens were made to increase their activity by means of periodic stimuli from an induction coil. 29 hens have been subjected to exposures to alcohol-vapor varying from 2 to 29 hours in duration. In addition, two sets of 3 fowls were subjected to alcohol-vapor periodically from 4 to 6 hours a day over several months to obtain information regarding the concentration in hens habituated to alcohol-vapor. Three dead hens were also exposed under the same conditions as outlined for the purpose of studying the rôle of diffusion in reference to distribution and concentration. A preliminary report of some of the data obtained was given at the 1919 meeting of the American Federation of Biological Societies. At the present writing it is planned to extend the research to other animals and to include in the study the determination of the alcohol utilized and the amount and character of the metabolism during exposure.

Acquisition of skill in pendulum-pursuit test.—While the pendulum-pursuit test was originally designed to meet the needs of a simple test of this nature for use with aviation candidates, it may be made a general test of the hand-and-eye coordination. Before using this method in other researches, it was desirable to obtain normal data which would give Dr. Miles information on the range of individual differences and the amount of improvement that might be expected

with successive trials. A group of 20 adults, mostly women, were given a practice series of 20 trials a day for 35 days. The data, most of which were collected by Mr. E. S. Mills, will be prepared for publication at an early date.

Preliminary experiments with pursuit-meter apparatus.—Dr. Miles's pursuit-meter apparatus has unique advantages in measuring ability for accurate continuous work. Immediately at the end of a test period, one may read directly from the meters the integrated score for the duration and magnitude of errors made by the subject. The score for a test period of 5 minutes has been found in preliminary experiments to range from 4,000 to 400 meter units, according to the age, intelligence, and practice of the individual used in the experiment. The task is found to be so simple that a child 5 years old can do it with some degree of proficiency, while there is sufficient latitude for the efforts of the keenest adult. A large number of trials have been made on a few subjects to determine the best lighting conditions, to obtain practice curves, and to improve the experimental routine.

Metabolism during muscular work.—Although no experimental work was done last year on metabolism during muscular work, the results of the earlier extensive study on metabolism during walking, carried out by Dr. H. M. Smith, is in an advanced state of preparation for publication. Plans have been made for direct calorimetric measurement of the metabolism during severe muscular activity by means of a specially constructed calorimeter. In anticipation of increased need of space for these studies, two of the older respiration calorimeters have been demolished to provide space for more modern apparatus.

Metabolism of normal children.—Studies on the basal metabolism of normal children from 2 years of age to puberty have been continued in cooperation with Dr. Fritz B. Talbot, at the New England Home for Little Wanderers, and with the assistance of Miss Inza A. Boles and Mrs. Dorothy A. Peabody. The studies were concluded on July 1, 1919, as sufficient material had been accumulated to give a reasonably complete picture of the metabolism of children from birth to puberty. A report of the later studies, with a general survey of the whole field covered by the series of investigations, is being prepared for publication. A summary of the findings in the research on this subject was presented by the Director as the Shattuck lecture at the meeting of the Massachusetts Medical Society in June 1919.

Studies of metabolism with varying environmental temperatures.—The studies on the effect of varying environmental temperatures upon the metabolism have been extended this year, the subject being the same artist's model used in last year's experimenting. The stimulating effect of various foods was a feature of the series of observations under these conditions. The clinical respiration chamber was used for the measurements of the respiratory metabolism. Near the conclusion of

the research, this chamber was placed inside the group respiration chamber, thus insuring complete control of the temperature environment. The investigation was carried out in cooperation with Miss Alice Johnson and Miss Marion L. Baker.

Survey of skin temperature, with photographic records.—The apparatus used for measuring the skin temperature in the research just cited was so nearly instantaneous in its action that it was possible, by means of a sensitive string galvanometer, to secure temperature curves from a large number of points on the body. In cooperation with Dr. Miles, photographic records were obtained of the deflections of the galvanometer and a complete survey of the temperature of the skin in different parts of the body was thus made. These topographical studies were carried out with environmental temperatures varying from 14° to 30° C. Miss Alice Johnson and Miss Marion L. Baker also assisted in these observations.

Study of metabolism of large animals.—In continuation of the research on undernutrition which was made with men at the International Y. M. C. A. College, Springfield, Massachusetts, in the winter of 1917–18, a study of the metabolism during undernutrition and in the subsequent period of realimentation has been begun with full-grown steers at the New Hampshire Agricultural Experiment Station, Durham, with the cooperation of Professor E. G. Ritzman. A large respiration chamber has been built and experiments made throughout the winter, spring, and fall, with the technical assistance of Miss Alice Johnson and Miss Mary Hendry. The special purpose of the research was to study the influence of submaintenance rations in the wintering and subsequent fattening for market of farm animals. 12 steers of uniform type and weight were divided into four groups of 3 animals each. The observations were begun in November 1918. A roughage maintenance ration was first given the animals for a preliminary period to establish the normal needs. The maintenance ration was then reduced one-fourth, one-third, and one-half, respectively, with three of the groups, the fourth group being fed on a maintenance ration to serve as a control upon the other three groups. Careful records were kept of the body-weights, pulse-rates, and rectal temperatures, and almost daily observations were made of the gaseous metabolism in the respiration chamber, including records of the activity during the experimental period. In May 1919 realimentation was begun, with liberal feeding. When the animals are in market condition they will be slaughtered and observations made of the condition, quality, and weight of the carcass, with especial attention to the effect of the prolonged period of submaintenance feeding upon the rapidity and character of the fattening. It is expected that the research will be continued during the coming year with steers, and possibly other farm animals.

The calorific value of extra foods.—The determination of the calorific value of such foods as are frequently taken outside of the regular meals,

or so-called "extra foods," has been continued by Mrs. Cornelia Golay Benedict. Among the food materials studied the past year are various cream cheeses, candies (mostly of the penny variety), sardines, olives, nuts, doughnuts, and a number of crackers. A second report of the results of this study has been prepared for publication. In this investigation Mrs. Benedict has been assisted by Miss Mary D. Finn and Mrs. S. C. Stickney.

Metabolism of cold-blooded animals.—As Mr. Edward L. Fox was called into National service in the summer of 1918, the researches at the New York Zoological Park on the metabolism of cold-blooded animals, and especially of snakes, were discontinued for a time, but were resumed in July 1919.

Editorial and computing work.—The two monographs published this year, *i.e.*, the report of the study on metabolism during undernutrition, a book of 700 pages, and the biometric study of basal metabolism of man, with its novel and hence especially guarded technicalities, required the major portion of the time of several members of the staff during the year for proof-reading and attention to the numerous technical details. A number of journal articles have also been prepared, giving summaries of results which will appear later in more detail in other publications. Several monographs and journal articles are now in preparation for publication. The mass of experimental material which has accumulated in the various researches required a temporary enlargement of the computing staff. Plans are being made for printing in permanent form the various tables, formulæ, etc., employed in computing metabolism experiments, for the general use of investigators.

PUBLICATIONS.

The following publications have been issued during the present year:

(1) The sex expression of men living on a lowered nutritional level. W. R. Miles. Journ. Mental and Nervous Disease, 49, 208 (1919).

This paper gives a detailed presentation of sex data collected in connection with the low-diet investigation reported in the monograph entitled Human Vitality and Efficiency under Prolonged Restricted Diet (Carnegie Inst. Wash. Pub. No. 280, 1919). The introspective accounts which form the basis of this paper were obtained under the most favorable circumstances. Of the 24 individuals studied, 22 report a decrease in sex interest and expression associated with the period of undernutrition. Any recommendation for general reduction in diet must therefore regard the probable effect on the sex instinct. The results suggest a method of treatment for achieving restraint in pathological cases.

(2) The concentration of alcohol in the tissues of hens after inhalation. T. M. Carpenter and E. B. Babcock. Proc. Am. Physiol. Soc., Am. Journ. Physiol., 49, 128 (1919).

An abstract presented at the 1919 meeting of the American Federation of Biological Societies of some of the data obtained in the investigation of the concentration of alcohol in the tissues of hens after inhalation.

(3) Gaseous exchange with unpracticed subjects and two respiration apparatus employing three breathing appliances. M. F. Hendry, T. M. Carpenter, and L. E. Emmes. Boston Med. and Surg. Journ., 181, 285, 334, and 368 (1919).

The respiratory exchange of 17 medical students, unpracticed with regard to respiratory studies employing breathing appliances, was measured in duplicate determinations with the portable respiration apparatus (Benedict) and a respiratory-valve apparatus, using mouthpiece, pneumatic nosepieces, or a half-face mask. Six different sequences of combinations of breathing appliance and respiration apparatus were utilized. All subjects were awake, inactive, and in the post-absorptive state. The averages of all results with the two types of respiration apparatus and the averages of the results obtained with the three breathing appliances are given in the table herewith.

Average of results obtained in the measurment of respiratory exchange with 17 unpracticed subjects.

[Values per minute.]

Apparatus.	Carbon dioxid.	Oxygen.	CO_2/O_2.	Heart rate.	Respiration rate.	Total ventilation.	Volume per respiration.	Expired air.	
								CO_2	O_2 deficit
With 2 types of apparatus:	c.c.	c.c.				liters.	c.c.	p. ct.	p. ct.
Portable	202	238	0.85	63	14.5	6.47	556	3.22	3.77
Respiratory valve	190	233	.82	65	14.2	5.26	464	3.67	4.48
With 3 breathing appliances:									
Nosepieces	196	235	0.84	64	13.8	5.40	494	3.72	4.41
Mouthpiece	201	238	.85	64	14.5	5.83	503	3.52	4.17
Mask	191	235	.81	65	14.7	6.36	534	3.10	3.80

The specific practical applications and recommendations in regard to clinical use of apparatus for the measurement of the respiratory exchange are as follows: All of the combinations of respiration apparatus and breathing appliances give reliable results in the measurement of oxygen consumption. The most efficient combination for this purpose is the portable respiration apparatus and mouthpiece; when only basal metabolism is desired, the measurement of oxygen consumption alone is sufficient. When it is desired to investigate the action of food and drugs upon both the character and the quantitative relationships of metabolism, the respiratory-valve apparatus and mask, with a practiced subject, is the only combination that will give reliable scientific results.

The oxygen consumption and respiratory quotient during the period between 8^h30^m a.m. and 12^h30^m p.m., with the subject in the post-absorptive state, awake, and at rest, do not show material change in level on the basis of the average of results obtained with the 17 men.

(4) A biometric study of basal metabolism in man. J. Arthur Harris and Francis G. Benedict. Carnegie Inst. Wash. Pub. No. 279 (1919).

This volume presents a first attempt at a more refined analysis of the data of basal metabolism by means of the higher statistical or biometric formulæ. Measurements of 136 men, 103 women, and 94 new-born infants, all of which

have been made at the Nutrition Laboratory or by those working in cooperation with it, serve as a basis of the conclusions drawn. The original data, many of which have not heretofore been published, are given in full.

These data, the most extensive series as yet available, have been summarized in terms of statistical constants (means, standard deviations, coefficients of variation, coefficients of correlation, and regression equations) which must serve as standard constants in metabolism work until those based upon more extensive series of data are available.

The relationships between certain of the physical and physiological measurements of the human individual, and between the various physiological measurements, have been expressed in terms of correlation coefficients and represented by regression equations. The effect upon these correlations of correction for other variables has also been discussed. The results from the data already available amply illustrate the material advances in our knowledge of physiological processes which may be expected when the interrelationship of the physical and physiological variables shall be generally expressed on a quantitative scale.

The change in metabolism with age during the period of adult life is investigated in detail and equations for the correction of metabolism for age have been given. The decrease in basal metabolism with age during the period of adult life is approximately linear.

The differentiation of the sexes in metabolic activity is considered, with the result that men have been shown by all of the series of tests applied to have a higher basal metabolism than women.

The validity of the so-called body-surface law has been tested by criteria hitherto unemployed. This "law" has been discussed as an empirical means of predicting the metabolism of an unknown subject and as an expression of a true physiological interrelationship. It has been shown that, as a basis for predicting the metabolism of an unknown subject, body-surface as estimated by any of the formulæ as yet available is inferior to equations given in this volume. Grave doubt has also been thrown upon the physiological significance of the so-called law.

In connection with the investigation of the "body-surface law," various methods of predicting the metabolism of an unknown subject have been considered and it has been shown that the most satisfactory results are obtained by the use of multiple regression equations involving stature, weight, and age. Standard tables have been prepared for men and women from which the most probable metabolism of a subject whose normal basal metabolism is unknown may be easily determined.

Illustrations are given of the wide usefulness of such tables in investigating the problems of the typical or atypical nature of series of metabolism measurements, the problem of the differentiation of the sexes with respect to metabolic activity, of the metabolism of athletes as compared with non-athletic individuals, and of individuals suffering from disease.

(5) A biometric study of human basal metabolism. J. Arthur Harris and Francis G. Benedict. Proc. Nat. Acad. Sci., 4, 370 (1918).

An abbreviated presentation of the material in Publication No. 279, Carnegie Institution of Washington (1919).

(6) Biometric standards for energy requirements in human nutrition. J. Arthur Harris and Francis G. Benedict. Sci. Monthly, 8, 385 (1919).

An outline of some of the problems which require consideration in establishing normal standards for work in human nutrition is given in this paper, which was preliminary to the detailed report of the biometric study of basal metab-

olism of man in Publication No. 279 of the Carnegie Institution of Washington (1919). (See abstracts 4 and 5.) The data for a large number of men, women, and new-born infants are briefly discussed analytically, and their relationships graphically illustrated. The frequencies of total heat production and heat production per square meter of body-surface, and the coefficients of variation on the basis of total heat production per 24 hours, are given, the latter being greater than that for stature, less than for body-weight, and approximately the same as for pulse-rate. To show the relationships between physical characteristics and basal metabolism, a comparison is made by the use of correlation coefficients. Those between body-weight and metabolism are higher than the coefficients between stature and metabolism while those between the metabolism and body-weight and body-surface, respectively, are approximately of the same magnitude. By the use of partial correlation formulæ this increase is shown to be not merely an interrelationship, as both stature and body-weight have an independent significance in indicating the daily heat production. The relationship between metabolism and age is also discussed. As a result of this analysis of metabolism data multiple prediction equations are suggested for predicting the daily caloric output of individuals of both sexes from body-weight, height, and age. Graphic illustrations are given of the ways in which these equations may be practically applied.

(7) The energy loss of young women during the muscular activity of light household work. Francis G. Benedict and Alice Johnson. Proc. Am. Phil. Soc., 58, 89 (1919).

To supply exact information regarding the energy requirements for light household work, the Nutrition Laboratory has begun a study of the heat output of women in various domestic activities. A preliminary report of the observations was given at the meeting of the American Philosophical Society in April 1919. The subjects thus far studied have been young women from the domestic science department of Simmons College, approximately 200 women taking part in the experiments. The apparatus used for determining the carbon-dioxid production was the group respiration chamber, previously referred to in the annual reports, with which 25 or more individuals can be studied simultaneously.

In all, 12 experiments were made, covering 48 periods 20 or 25 minutes in length. To provide a standard for computing the increase in energy required for the particular household occupation studied, the energy loss of the groups of young women while sitting quietly reading 2 hours after a light breakfast was determined at the beginning of every experiment in from 1 to 3 periods. As a result of 23 rest periods on 12 experimental days, it was found that the average heat output per kilogram per hour was 1.12 calories. This average figure of 1.12 calories has a specific interest in that it indicates the probable heat production of women sitting quietly under ordinary living conditions with a moderate amount of food in the stomach.

In the three experiments when the women read aloud, the increments found were 3, 1, and 5 per cent, respectively, with an average of 3 per cent. With the subjects singing, the increments were 17, 34, and 16 per cent, respectively, with an average of 22 per cent. In the two experiments with the women doing plain sewing (hemming), increments of 16 and 10 per cent were found, with an average of 13 per cent. One experiment was made with a group of women standing quietly, which gave an increment of 9 per cent. With a group of women sweeping, increments were obtained in two experiments of 139 and 161 per cent, with an average of 150 per cent. Three experiments in which the subjects dusted chairs showed increments of 126, 121, and 156 per

cent, with an average of 134 per cent. In the two experiments in which the young women stood up and immediately sat down again, it was found that an energy expenditure of approximately one-third calorie was required per individual and per movement for this activity. In the one experiment in which the women walked about the chamber for 25 minutes at the slow rate of 1.08 miles an hour, the extra energy due to the walking was 1.24 calories per kilogram per hour. As the average weight of the subjects was 54 kilograms, the activity of walking therefore required an average extra expenditure of energy for each individual of 62 calories per mile.

(8) The temperature of the human skin. F. G. Benedict, W. R. Miles, and Alice Johnson. Proc. Nat. Acad. Sci., 5, 218 (1919).

In April 1919 a preliminary report of the study begun at the Nutrition Laboratory on the temperature of the human skin was presented at the meeting of the National Academy of Sciences at Washington. The apparatus employed to give true records of the skin temperature consists of two copper-constantan junctions, one of which is located in a constant-temperature bath, with a temperature not far from 31° to 32° C., and the other is applied to the skin. The latter is protected from the environmental temperature by a backing of cotton and a rigid installation in hard rubber. When the junction is placed upon the body, it assumes the temperature of the skin in 6 seconds. Readings of a galvanometer in series, referred to a calibrated standard, give the direct values for the skin temperature. The subject used in the study (an artist's model) was able to withstand relatively low temperatures, without discomfort or shivering. It was thus possible to make topographical studies of skin temperature with environmental temperatures of 14° to 30° C.

By moving the thermal junction at a moderately rapid rate over the skin surface, and the use of a sensitive string galvanometer, temperature curves were thus obtained from an infinite number of different points on the body, the deflections of the galvanometer being recorded photographically. From periodic observations of the skin temperature, information was obtained as to the rapidity of the change in this factor after exposure of the body and also as to the absolute level to which the skin temperature falls after prolonged exposure to different degrees of cold. Observations were made under ordinary clothing, also with the subject nude. Under the clothing the values ranged on a typical day from 28.1° to 34.7° C., with a difference of 6.6° C. After exposure of two or more hours to an environmental temperature of approximately 14° C., they ranged from 19.1° to 29.7° C., with a difference of 10.6° C. At a temperature of 30° C., the skin temperature at various points on the body showed an extreme variation of 4.2° C.

(9) Energy requirements of children from birth to puberty. Francis G. Benedict. Boston Med. and Surg Journ., 181, 107 (1919).

In this paper, which was presented as the Shattuck lecture to the Massachusetts Medical Society in June 1919, a history is given of the research on the energy requirements of normal children which has been conducted the past 8 years by the Nutrition Laboratory. Some of the infants studied, notably those of wet-nurses, were followed up for several years and observations made from time to time, giving results for the same individual during a period of rapid growth. The apparatus used is described and illustrated, typical kymograph curves are given showing pulse-rate and degree of muscular activity or repose, and the results obtained in the 8 years of investigation

are summarized and compared. Emphasis is laid upon the fact that "normal" and "average," when used in considering data obtained with children, are not synonymous terms, owing to the large proportion of underweight children. The suggestion is made that, for a basis of comparison, the weight as compared with height is more logical than the weight as compared with age.

Charts are given comparing the minimum or basal heat production of new-born infants on the basis of age; also a chart showing the heat production of a normal infant at various times during a period of 4 years. The observations with the normal children studied are summarized for boys and girls separately in a number of graphic comparisons, in which the basal heat production per 24 hours is considered on the bases of age, body-weight, and body-surface. A comparison is made of the data for boys and girls to determine the influence of sex, and of both boys and girls with results for men and women to show the difference between the metabolism in the period of growth and in adult life. The influence of approaching puberty is also considered.

"From these charts it is clear that at a very early age, *i.e.*, with low weights, the metabolism is specifically low. It then rises rapidly until the child's weight has increased to approximately 10 kilograms, when it is at its maximum per unit of weight and per unit of area. There is next a steady decrease until approximately 30 to 40 kilograms, when the early adult period begins." "It must be borne in mind that in the making of such curves there is danger of misinterpretation as to the fixity of the lines, and it should be remembered that they represent trends only." "Up to 8 kilograms no differences in the sexes are to be noted, but thereafter the boys have a somewhat higher heat production on the whole, thus indicating a specifically somewhat higher metabolism with the growing boy than with the growing girl."

The details of the earlier studies with infants are given in Publications Nos. 201 and 233 of the Carnegie Institution of Washington. The complete results of the later investigations, including those with the older boys and girls, are being prepared for publication.

(10) Human vitality and efficiency under prolonged restricted diet. Francis G. Benedict, Walter R. Miles, Paul Roth, and H. Monmouth Smith. Carnegie Inst. Wash. Pub. No. 280 (1919).

A detailed abstract of the results obtained in the study of human vitality and efficiency with a prolonged restriction of diet was given in the previous annual report in reviewing a preliminary report of the findings of this research. (See "The effects of a prolonged reduced diet on twenty-five college men" in the annual report of the Director for 1918.) It thus appears unnecessary to give a further abstract of the results here.

(11) The energy content of extra foods. (Second paper.) Cornelia Golay Benedict and F. G. Benedict. Boston Med. and Surg. Journ., 181, 415 (1919).

A report of the latest results of the study on the energy content of "extra foods" is given in the second paper of this series, in which a considerable number of food materials used on picnics, automobile tours, and for incidental meals are treated of. The energy content is given of olives and olive products, sardines, nuts, potato chips, doughnuts, confectionery (especially the "penny candies"), cream cheeses, popcorn, crackers, and pretzels. In view of the increasing use of refined sugar in American homes, the caloric value of ordinary servings of granulated sugar and the weights and sizes of various lump sugars are also discussed. The method followed in determining the energy values reported in the first paper, *i.e.*, the direct determination of the caloric value by means of the bomb calorimeter, was used for these food materials.

The ordinary bottled olives of average size had a caloric value per olive of 8 to 10 calories, extra large olives 14 to 15 calories, and small olives, including stuffed olives, 4 or 5 calories. "Olive butter," sold for use in sandwiches, supplied approximately 10 calories in a level teaspoonful. The popular sardine (American brands) showed an energy value of 221 to 533 calories per can, with 15 to 26 grams of protein. The two samples of imported sardines had an energy value per can somewhat higher than the American brands, *i.e.*, not far from 500 calories. Owing to their high fat-content, the nuts analyzed gave an energy value per gram of from 7.0 calories (peanuts) to 7.9 calories (filberts). Thus, 10 half walnuts contain nearly 150 calories and 10 peanuts 60 calories. Potato chips contained an average of 5.9 calories per gram, 544 to 714 calories a box, and somewhat over 130 calories in one average "helping." Doughnuts (6 samples) showed an energy value of 4.4 to 5.1 calories per gram, individual doughnuts yielding 151 to 256 calories, or 200 calories on the average. A single oyster cracker was found to give, on the average, 3.5 calories, while a pretzel supplied about 19 calories. Of the variety of candies examined, caramels had an approximate value of 50 calories per caramel; chocolate-coated candies ranged from 12.9 calories for a small chocolate almond to 83 calories for a large nougatine, while chocolate peppermints gave 33 to 54 calories each. Several miscellaneous candies containing no chocolate supplied less energy than the chocolate candies, a gum-drop yielding about 35 calories, a mint candy 5.3 calories, a marshmallow 13.4 calories, and a cough-drop 11.4 calories. The penny candies gave from 50 to 60 calories for a cent and in two instances over 100 calories. Popcorn cakes supplied 4 calories per gram and cream cheeses from 2.06 to 3.65 calories per gram. A study made of the measurement of a spoonful of sugar showed a wide variation in the amounts obtained by 17 individuals. A teaspoonful of sugar contained 29 to 35 calories, while the caloric content of a spoonful measured with a "sugar spoon" was 41 calories. Lump sugar, full size, gave 24 to 29 calories, and 18 calories half size. The relationship between the consumption of these extra foods and the 24-hour requirement is briefly discussed.

DEPARTMENT OF TERRESTRIAL MAGNETISM.*

LOUIS A. BAUER, DIRECTOR.

GENERAL SUMMARY.

INTRODUCTORY REMARKS.

The closing of the great conflict among nations interested in the advancement of scientific work, especially work of international character and scope, has made it possible for the Department of Terrestrial Magnetism to return, though slowly, to its normal activities. Members of the scientific personnel, both those directly and those indirectly engaged in winning the war for humanity and science, have gradually resumed their pre-war duties in the Department. However, great difficulties are being encountered, which may be expected to continue for some time to come, in the resumption of the Department's full program of pre-war days, because of the excessively high costs of maintenance and operations. Thus the cost of maintaining the *Carnegie* in full sea-service will be somewhat more than twice that before the war. The same is true of other portions of the Department's work.

Unless, therefore, the annual funds heretofore available to the Department are increased considerably, a reduction of the usual program will be imperative. If the latter step must be taken it will be all the more unfortunate for the cause of international research in geophysics, since we may not look forward confidently to receiving cooperation from the nations, impoverished by the war, to the same extent as in pre-war days. The setback to science for many years to come is one of the most unfortunate results of the great war.

The facts just stated indicate sufficiently why it has been necessary to proceed slowly with the resumption of observational and investigational work. The main endeavor has been to unite, as far as possible, the threads severed by the war, and to bring to a conclusion such researches as had already been under way rather than undertake or begin anything radically new.

OCEAN MAGNETIC WORK.

The rapid deterioration of a modern-built wooden vessel while lying idle at port, as the *Carnegie* was obliged to do after her arrival at Washington in June 1918, decided the Executive Committee of the Institution to authorize in February 1919 the complete overhauling and putting in good repair of the vessel for another cruise of world-wide extent. An additional appropriation for this purpose was accordingly made by the Executive Committee, which funds, supplemented by accumulated Department balances from previous years, sufficed to put the *Carnegie* in first-class condition for full sea-service. A detailed statement as to alterations and repairs will be found in Commander Ault's report (pp. 284-285).

*Address, Thirty-sixth Street and Broad Branch Road, Washington, D. C.

The *Carnegie* left her home port, Washington, October 9, 1919, for a cruise (No. VI) of 64,000 nautical miles, requiring somewhat over 2 years for completion. For the first 6 months she will be cruising mainly in the South Atlantic Ocean, where the completion of her work in 1917 was made unsafe during the war. Thence, after extending the work in the Indian Ocean, carried out on the *Carnegie* in 1911, she will make such cruises in the Pacific Ocean as are designed not only to cover large areas not magnetically surveyed, but also to determine by intersection of previous tracks of the *Carnegie* and of her predecessor, the *Galilee*, the changes ever going on in the Earth's magnetism. These changes, of course, will also be determined in the other oceans traversed by again arranging the vessel's tracks so as to secure, as often as possible, frequent intersections with previous tracks of the *Carnegie*.

The heavy demand for vessels in the resumption of traffic and commercial intercourse will probably make it impossible in the near future for other countries to engage, or to participate, in ocean observational and investigational work. It would seem, then, that added responsibility is put upon us, and that we may have to regard it as our duty, in spite of the heavy additional cost, to maintain the *Carnegie* in full operation, certainly until a time when other nations have recuperated sufficiently to share adequately in the promotion of work and researches of international benefit and concern. The statement of the hydrographer of the British Admiralty, received in July 1917, to the effect that in the preparation of the navigator's magnetic charts for 1917 chief dependence for new information had to be put upon the magnetic work of the Carnegie Institution of Washington, will, doubtless, have to be the case for some time to come in future editions of these charts.

LAND MAGNETIC WORK AND ECLIPSE OBSERVATIONS.

For reasons already stated, it was possible to resume the field observational work only to a limited extent. The field work successfully accomplished during the period November 1918 to October 1919 is briefly as follows, the details being given on pages 286-291.

1. *Africa.*—Observer Frederick Brown, after discharge from the British Army, reentered the employ of the Department on March 1 and, after preparations under the Director's guidance at London, sailed from Liverpool on April 8 for Douala, Cameroun, where he arrived May 2. After securing repeat observations at various stations, he participated in the international eclipse magnetic observations of May 29, his station being Campo, Cameroun, about 100 miles north of the belt of totality. He next set out on June 11 for an overland trip through the interior of Cameroun, from Kribi to Fort Lamy, near Lake Tchad. Thence he will return to Douala via a route through the western part of the French Kongo.

   In connection with the eclipse observations at Cape Palmas, Liberia, 3 magnetic stations were occupied in the vicinity by the Director and Magnetician H. F. Johnston.

2. *Africa and Asia.*—Observer H. E. Sawyer, returning from his extensive work in Central Africa, as described in previous reports, secured magnetic observations during November and December 1918 at various stations, some of which were repeat stations, where the Department had previously made observations.

Early in January 1919 magnetic observations were received from Capt. R. Amundsen, made at 3 stations along the Siberian coast with the magnetic instruments loaned the Amundsen Polar Expedition by the Department (see Annual Report for 1918, p. 240). These stations were at Vaigach (latitude 69°.7 N., longitude 60°.2 E.), occupied August 12–13, 1918; Khabarowa (latitude 69°.7 N., longitude 60°.4 E.), occupied August 15, 1918; and Port Dickson (latitude 73°.5 N., longitude 81° E.), occupied September 2–3, 1918. The second station was probably close to the 1893 station of the Norwegian North Polar Expedition.

Professor Boris Weinberg, of the University of Tomsk, Siberia, was loaned a land dip-circle to complete the magnetic outfit with which he hopes to secure in 1919 some cooperative observations in Siberia.

3. *Australia.*—(See observatory work at Watheroo, p. 291.) Cooperation was received in the continuation of the magnetic survey of South Australia from Government Astronomer G. F. Dodwell, Adelaide Observatory, and Professor Kerr Grant, University of Adelaide. These investigators are using a magnetometer, as well as directions and forms, supplied by the Department. Their work, as shown by the cahiers of observations received at Washington, is carefully done and forms a valuable contribution.

4. *North America.*—Magnetician H. W. Fisk and Observers H. R. Grummann and R. R. Mills carried out a series of magnetic observations at 13 stations along the lower shores of Chesapeake Bay. The prime purpose of this work was in connection with the reduction of the past and future "swing observations" of the *Carnegie* in the Chesapeake, off the Patuxent River. For observational and instrumental work at Washington, see pages 293-294.

5. *South America.*—Observer A. Sterling, after discharge from the American Army, was assigned to field work in Chile and Argentina. He arrived at Valparaiso on March 19, 1919, and after repeat observations at Santiago and Puerto Montt, reached Punta Arenas, Chile, on April 6, making observations here as well as en route. Thence he proceeded to occupy stations chiefly along the eastern coast of Argentina. At a number of his stations, magnetic observations had been made previously under the auspices of the Meteorological Service of Argentina. He occupied a former station of the Department at Colon, Uruguay, and also obtained comparisons with the magnetic standards at the Vassouras Observatory, Brazil.

For an account of the work of Dr. H. M. W. Edmonds's party in Peru, see Observatory Work, page 291, and Eclipse Work, page 290.

Observer D. M. Wise's party, besides carrying out the full program of eclipse work at Sobral, Brazil, described on page 290, made magnetic observations at 11 stations in eastern Brazil and at Barbados; at 4 of these stations the Department had made observations previously.

ECLIPSE OBSERVATIONS.

In connection with the total solar eclipse of May 29, 1919, the belt of totality of which passed through Chile, Bolivia, Brazil, Southern Liberia, French Kongo, Kongo State, and British East Africa, the Department made geophysical observations at various stations and also secured cooperation at stations the world over, inside and outside the region of visibility of the eclipse. The observations at many of these cooperating stations have already been received.

The Department's observations were as follows:

Inside the totality-belt.—Magnetic, electric, meteorological, and shadow-band observations at Sobral, Brazil, by Observers D. M. Wise and A. Thomson, the sky being clear during totality, which lasted here a little over 5 minutes; and at Cape Palmas, Liberia, by the Director and Magnetician H. F. Johnston. Totality lasted at Cape Palmas the unusual length of 6¼ minutes and the sky was almost entirely clear throughout the eclipse, from beginning to end. For results, see abstract, page 311.

Outside the totality-belt.—Huayao, Peru, by Dr. H. M. W. Edmonds and Assistant Observer F. G. Rosemberg; Puerto Deseado, Argentina, by Observer A. Sterling; Campo, Cameroun, by Observer F. Brown; Watheroo Observatory, West Australia, by Magnetician W. F. Wallis and Observer W. C. Parkinson; and at Washington, D. C., by Computer C. R. Duvall. Only Watheroo and Washington were outside the region of visibility of the eclipse.

OBSERVATORY WORK.

Western Australia.—The buildings for the magnetic work were completed in time to begin the photographic registration of the magnetic variations on January 1, 1919. The inauguration of the work in terrestrial electricity has had to be deferred until 1920, the present heavy costs and difficulties of construction making it imperative to postpone the erection of the required auxiliary buildings. After three years' faithful and arduous work, it will be possible, toward the end of the fiscal year, to relieve Mr. W. F. Wallis, who has been in charge of the constructional and observational work at Watheroo since 1916. Magnetician E. Kidson, after his discharge from the British Army in June, reentered the employ of the Department and will assume charge of the Watheroo Observatory in October 1919. Observer W. C. Parkinson, as in the past, has been the chief assistant at this station.

Peru.—In view of the extensive experience now gained by Dr. H. M. W. Edmonds in observatory work and field work in terrestrial magnetism, he was detached from service as surgeon and magnetician aboard the *Carnegie*, and intrusted with the responsible task of the construction and equipment of a magnetic observatory in Peru at Huayao, near Huancayo, situated about 125 miles east of Lima, at an elevation above sea-level of about 11,000 feet. Dr. Edmonds arrived at Lima in March and is making as rapid progress as the conditions permit. He is assisted by Assistant Observer F. G. Rosemberg, a

native of Lima, who secured his collegiate training at Syracuse University, New York. Furthermore, A. Smith, carpenter, was sent to Peru in June to assist Dr. Edmonds.

Washington.—The atmospheric-electric work at Washington was conducted throughout the year under the charge of Dr. S. J. Mauchly, in the small house erected on the deck of the laboratory.

Comparisons of magnetic instruments have been made from time to time at the Standardizing Magnetic Observatory at Washington, as well as at various foreign observatories. For details regarding the Observatory work, see pages 291-293.

RESEARCH WORK IN WASHINGTON.

TERRESTRIAL MAGNETISM.

The return to normal activities has made possible further progress with the manuscript for Volume IV of the Researches of the Department. This volume will contain the results of the land magnetic observations, 1914 to 1919, those of the ocean observations 1917 and 1918, besides monographs on special subjects. It is hoped now that the manuscript will be completed by the end of 1919.

The extensive observations made in connection with the total solar eclipse of June 8, 1918, by the Department and by many cooperating observatories, were reduced and discussed and published in final form in the issues of *Terrestrial Magnetism and Atmospheric Electricity* for September and December 1918, and March and June 1919. The results will be found summarized on pages 306-308. It is believed that the gratifying cooperation received and the prompt transmission of data, both with regard to this eclipse and the recent one of May 29, 1919, is to be attributed in some measure, at least, to the prompt reduction and publication of data.

In connection with various problems, the Director has had occasion to establish, in a form convenient for ready calculation, formulæ for the potential and field components of certain uniformly magnetized bodies, such as solid ellipsoids of revolution and elliptic homœoids. (See abstract, p. 308.)

Various theoretical investigations connected with military matters were brought to a conclusion and may be reported upon at some future time.

Improvements in reduction-methods of field observations have been made by Mr. Fisk, as shown in the abstract, page 313.

The design of a sine galvanometer for measuring the field intensity of the Earth's magnetism with great precision and rapidity has received further improvement at the hands of Dr. Barnett, and the construction in the Department's shop has been begun. For improvements in other instrumental matters, see pages 299-301.

Those taking chief part in the investigational work of terrestrial magnetism at Washington were: L. A. Bauer, S. J. Barnett, W. J. Peters, J. A. Fleming, J. P. Ault, H. W. Fisk, C. R. Duvall, C. C. Ennis, and H. B. Hedrick.

For further accounts of above work, see abstracts, pages 302-316.

MAGNETISM IN GENERAL.

By December 1919, it is hoped that the non-magnetic building, known as the experiment building and erected under Mr. Fleming's charge on the Department's site at Washington, will be ready for use in special experimental work pertaining to fundamental problems in magnetism. For details of construction, see pages 301 and 302.

The following chief problems, besides those elsewhere mentioned, have engaged Dr. Barnett's attention during the year:

(*a*) The investigation of certain aspects of crystal magnetization.
(*b*) Continuation of the experiments on magnet-photography, referred to in the annual reports of 1917 and 1918.
(*c*) Continuation of the experiments on magnetization produced by rotation and rotation produced by magnetization. (The completion of the Experiment Building will furnish exceptional facilities for these important experiments.)
(*d*) Method of determining the acceleration of gravity at sea with the requisite accuracy.

Dr. Barnett also gave a course of 26 lectures on theories of magnetism at the Laboratory between September 1918 to June 1919, which course was attended by members of the Department, U. S. Bureau of Standards, and U. S. Patent Office. For further accounts of work done by him, see page 294 and abstracts pages 304-306.

TERRESTRIAL ELECTRICITY.

In view of the growing importance of investigations in atmospheric electricity, earth-currents, and polar lights, a Section of Terrestrial Electricity, under the immediate charge of Dr. S. J. Mauchly and as a part of the work of the Division of Experimental Work, was formed at the beginning of the year. The following chief investigations engaged the attention of the section:

(*a*) Improved continuous registrations of the electric potential-gradient and electric conductivity of the atmosphere in the deck-house on the roof of the Laboratory at Washington.
(*b*) Reduction and discussion of the atmospheric-electric observations at Lakin, Kansas, in connection with the total solar eclipse of June 8, 1918. (See abstract, p. 307.)
(*c*) Methods, instructions, reduction, and discussion of the atmospheric-electric observations made by Mr. Wise's party at Sobral, Brazil, in connection with the total solar eclipse of May 29, 1919.
(*d*) Improvements in methods and instruments for the atmospheric-electric work on the *Carnegie*.
(*e*) Further critical studies of earth-current observations.

Chief assistance was rendered Dr. Barnett and Dr. Mauchly, by Messrs. D. M. Wise and A. Thomson, and occasional assistance by Messrs. H. R. Grummann, C. A. Kotterman, T. C. Kiesel, and M. B. Smith. For details of work, see page 296.

STANDARDIZING AND INSTRUMENT WORK.

The work under this head has continued in Mr. Fleming's charge. On pages 293 and 299 he makes a detailed report, from which the following synopsis has been prepared:

(*a*) Considerable work in the overhauling, improving, repairing, and constructing of instruments and appliances for the observational and experimental investigations of the Department was accomplished with the available shop-force.

(*b*) Compass-variometers in improved form were designed and constructed, as well as an inertia-gimbal system for the elimination of dynamic and magnetic deviations in instruments for use on shipboard.

(*c*) The string galvanometer (see p. 313), designed and constructed by the Department, was arranged for use with the marine earth-inductor on the *Carnegie*.

(*d*) Improvements in the *Carnegie's* equipment for ocean atmospheric-electric work.

(*e*) Partial construction of sine-galvanometer for measuring horizontal intensity of Earth's magnetic field. (See pp. 294 and 300.)

(*f*) Designing of the electric installation on the *Carnegie* and design and construction of the switch-boards for the *Carnegie* and the Experiment Building.

The Department has continued to make all non-magnetic castings for the various instruments in its own small brass foundry. The success achieved here has attracted the attention of others, who have applied for and received instructions in the methods employed.

The personnel of the shop consisted of Messrs. C. Huff, G. H. Jung, W. F. Steiner, instrument makers; A. Smith, carpenter and pattern-maker; J. G. Lorz, apprentice.

MISCELLANEOUS ACTIVITIES.

Besides the activities of members of the Department, described in the previous pages, an account will be found under "Abstracts" of papers contributed to learned societies and special conferences. In connection with the meeting of the American Physical Society, the Department took part in the display of instruments. From time to time the research committee of the Department has met in the Director's study for discussion and presentation of scientific subjects of special concern and interest.

The Director, after the return to England of his eclipse expedition to Cape Palmas, Liberia (see pp. 311-313), represented the United States Weather Bureau at the preliminary conference of official weather-

bureau directors called at London, July 3 to 9, by Sir Napier Shaw, president of the pre-war International Meteorological Committee. From July 18 to 28 he attended at Brussels, as delegate, by appointment of the president of the National Academy of Sciences, the meetings of the International Research Council, International Geodetic and Geophysical Union, and of other unions established by the council. A brief account of the actions taken at Brussels on matters of interest to the Department is given on pages 309-311. It will suffice to state here that a Section on Terrestrial Magnetism and Electricity of the International Geodetic and Geophysical Union was established and tentatively organized as follows: A. Tanakadate (Japan), president; Charles Chree (England), vice-president; Louis A. Bauer, secretary and director of the central bureau.

DETAILS OF OBSERVATIONAL AND EXPERIMENTAL WORK.

OCEAN-SURVEY WORK.

At the conclusion of Cruise V on June 30, 1918, the ocean-survey work was discontinued for the remaining period of the war. Dr. H. M. W. Edmonds continued in command of the *Carnegie* in Washington through December 1918, and had general supervision of the overhauling and dismantling of equipment and instruments. On December 31 he was relieved of command to take charge of and to prepare for the important work of acquiring a site and constructing the proposed observatory in Peru.

Mr. J. P. Ault resumed command of the *Carnegie* on January 1, 1919, and took up the general overhauling, repairing, and outfitting of the vessel for the resumption of the ocean-survey work. A cruise of 2 or 3 years was planned to start in August 1919, as it was expected that the repairs and alterations would then be completed. The unsurveyed regions in the South Atlantic and Indian Oceans are to be covered and the return is to be made through the Pacific Ocean and Panama Canal to Washington. The route is planned to obtain a large number of secular-variation observations, and will include calls at the following ports: Dakar, West Africa; Buenos Aires, Argentina; St. Helena Island; Cape Town, South Africa; Aden, Arabia; Perth, Australia; Lyttelton, New Zealand; Papeete, Tahiti, Society Islands; Fanning Island; Honolulu, Territory of Hawaii; Marquesas Islands; Balboa and Cristobal, Canal Zone; San Juan, Porto Rico; and return to Washington.

Early in 1919 it was decided to convert the *Carnegie's* engine to operate on gasoline instead of on producer gas. This change seemed desirable because gasoline can now be secured in all frequented ports of the world and because of the increase in efficiency and reliability of operation resulting from the use of gasoline instead of producer gas. In accordance with this plan, early in March 1919, the engine was

shipped to Jersey City, where the remodeling was carried out by the James Craig Engine and Machine Works, the builders of the engine.

On April 18, 1919, the *Carnegie* left Washington under tow, arriving at Baltimore the following day. The vessel was overhauled and extensive repairs and alterations were undertaken under the direction of the Spedden Shipbuilding Company of Baltimore. The vessel was hauled out on Booz Brothers marine railway on May 13, 1919, and was resheathed with yellow metal and copper. This work was completed on May 22, but upon attempting to haul the vessel down into the water again, the cradle of the marine railway left the track and could not be moved. Special launching ways were constructed, which required not only careful planning but also very much time, as practically all the work had to be done by divers. Every precaution was taken to insure the safety of the vessel during these operations. After numerous delays, the vessel was finally afloat again on August 21.

The *Carnegie* then returned to the Spedden Shipbuilding Company, where the remodeled engine was installed. For the storage of the gasoline, two copper tanks, each 6 feet in diameter and 10 feet long, were installed in the former producer room. Each tank carries 2,100 gallons of gasoline. Every care was taken in the construction of the tanks and in the installation of the entire power plant to insure safety in the storage and use of this fuel.

The installation of electric storage-battery for lighting and low power uses was an important addition. All fittings and fixtures were made of non-magnetic material wherever possible, and twisted cable was used for the circuits. The 1-kilowatt, 40-volt generator, which is to charge the storage battery, was mounted in the after end of the engine-room, as far as possible from the positions of the observing instruments. This generator is to be operated by the 6-horsepower kerosene engine at times when magnetic work is not in progress.

The delays in the completion of the gasoline tanks and in getting the *Carnegie* off the marine railway compelled a postponement of the sailing date from Washington until October 9.

The personnel of the *Carnegie* party is as follows: J. P. Ault, in command; H. F. Johnston, magnetician, second in command; Russell Pemberton, surgeon; A. Thomson and H. R. Grummann, observers; R. R. Mills, junior observer; A. Erickson, first watch officer; C. E. Leyer, engineer; L. Miehle, second watch officer; C. Strom, boatswain; 2 cooks; 1 mechanic; 8 seamen; 2 cabin-boys; the entire personnel thus consists of 23 men.

After completing the swing and standardizing magnetic and electric observations in the Chesapeake Bay, off Solomons Island, where the Director and Messrs. Fleming and Mauchly made a final inspection, she sailed from Hampton Roads October 19, bound for Dakar, Senegal, and arriving there after a stormy passage, on November 24.

LAND-SURVEY WORK AND SPECIAL EXPEDITIONS.

The war and the resulting world conditions have restricted land field work to a great extent during the year. It has been possible, however, to secure valuable data at new stations as well as secular-variation stations, particularly in Africa and South America.

An important problem concerning the land field work is that of securing absolute time for the determination of longitudes. Inquiry and study regarding wireless methods for the reception of time signals was undertaken. Mr. Brown particularly made inquiries regarding small portable types of receiving apparatus with a telephone relay instead of an amplifier system. It is hoped that a portable receiving outfit may be developed which will be compact and light enough to form part of the regular equipment of our field parties.

AFRICA.

In Africa, Messrs. Bauer and Johnston made magnetic observations at three stations in Liberia, one of these, namely, Russworm Island, being a close reoccupation of the station occupied by Observer Sawyer in 1914. These observations were made on the trip to carry out the special program of magnetic and atmospheric-electric observations during the solar eclipse of May 29 at Cape Palmas. (See p. 311.)

Observer F. Brown, who reentered the service of the Department on March 1 after his discharge from the British Army, made magnetic observations during April, while en route to the field, at Seccondee and at Accra on the Gold Coast. He arrived at Douala, Cameroun, on May 2, and made that point his headquarters for the work in Cameroun. After securing repeat observations at the C. I. W. 1915 station and at a secondary station at Douala, he worked along the Northern and Midland railways, occupying new stations at Nkong-Samba, Lum, Kompina, and Edea. During May 24 to June 2 he made special eclipse observations at Campo, Cameroun, on the coast midway between Douala and Libreville. He also occupied on June 3 a station at Rio Campo in Spanish Guinea. He left Kribi, Cameroun, June 11, for Fort Lamy near Lake Tchad, traveling via Ebolowa, Yaounde, Yoko, Tibati, Ngaumdere, Garua, and Dikoa; he arrived at Yoko on July 11 and expected to arrive at Dikoa early in August and to proceed thence to Nola and Wesso via Lai, Goré, Carnot, and the Kongo River. From Wesso he plans to return to Douala overland, via Molundu and Abong-Mbang, to railhead of the Midland Railway at Esseka, arriving at Douala probably early in December 1919.

ASIA.

At the end of the last report-year, Observer H. E. Sawyer was en route to the office after an extended survey trip in Africa from Lake Tchad overland to Khartoum and thence to repeat C. I. W. stations

Jeddah and Aden, Arabia, and Jibuti, French Somaliland. While returning he occupied during October to December 1918 a second station at Addis-Abeba, Abyssinia, in the vicinity of the first station occupied in this city in 1914 by W. F. Wallis, repeat C. I. W. stations at Colombo, Ceylon (1911), Singapore, Straits Settlements (1913, and a new station), and Sugita, Japan (1906). He arrived in San Francisco December 26, 1918, thus completing a field trip of over 3 years, during which time he observed at 170 stations, chiefly in Africa, of which a large number were reoccupations.

In January 1919 three cahiers of observations were received for stations in Siberia occupied by Captain R. Amundsen and his assistant, with magnetic equipment loaned by the Department (see report for 1918, p. 240). These stations were at Vaigach (latitude, 69°.7 N., longitude, 60°.2 E.), occupied August 12–13, 1918; Khabarowa (latitude, 69°.7 N., longitude, 60°.4 E.), occupied August 15, 1918; and Port Dickson (latitude, 73°.5 N., longitude, 81° E.), occupied September 2–3, 1918. The station at Khabarowa is probably close to the 1893 station of the Norwegian North Polar Expedition.

Professor Boris Weinberg of the University of Tomsk, Siberia, was loaned a land dip-circle and tripod to complete the magnetic outfit with which he hopes to secure in 1919 some observations in Siberia.

AUSTRALIA.

The only field stations occupied by the Department in Australia during the year were those at the absolute magnetic observatory near Watheroo, Western Australia.

Since the last report there have been received from Government Astronomer G. F. Dodwell, of the Observatory, Adelaide, cahiers of magnetic observations made in cooperation with the Department by the Geodetic and Magnetic Survey of South Australia by himself and Professor Kerr Grant at 11 stations in South Australia in September 1915, May 1916, February and March 1917, and January 1918. These form a valuable contribution to the magnetic survey of South Australia.

NORTH AMERICA.

Magnetician H. W. Fisk, with the assistance of Observers H. R. Grummann and R. R. Mills, carried out a series of magnetic observations at 13 stations along the shores of Chesapeake Bay below and opposite the mouth of the Patuxent River. This work was mainly to determine if any appreciable local disturbance exists about the region in the bay where the *Carnegie* was swung in June 1918 at the close of Cruise V and in October 1919 at the beginning of Cruise VI; the opportunity was also taken to instruct the new members of the party in field observations and practice. The results indicate a slight irregularity in the magnetic distribution over the region investigated, but the dis-

turbance effects on normal distribution over the area covered by the swings are probably less than the order of error of observations for results on shipboard.

Mr. Duvall made declination observations on May 28, 29, and 30, 1919, at the Standardizing Magnetic Observatory in Washington, in accordance with the special eclipse program.

SOUTH AMERICA.

In connection with the program of special magnetic observations during the eclipse of May 29, 1919, Dr. H. M. W. Edmonds and Assistant Observer F. G. Rosemberg obtained between April 11 and June 14 complete magnetic observations at the C. I. W. primary and secondary stations of 1917 at Huancayo, at the C. I. W. 1917 station at Huayao, and at the special eclipse station at Huayao for controlling the special variometer work.

Observer A. Sterling was assigned early in the year to carry out a series of observations at stations in Chile and in Patagonia, Argentina, to include reoccupations of stations occupied during 1913 by the Meteorological Service of Argentina and during 1917 by the Department in Argentina and Chile. After the necessary preparations, including conferences with officers of the Pan-American Union at Washington and with Professor Bailey Willis at New York, Mr. Sterling sailed on February 25 from New York for Valparaiso, where he arrived March 19. After making reoccupations of the C. I. W. 1913 stations at Santiago and Puerto Montt, Chile, he sailed on March 30 from the latter point for Punta Arenas, Chile, where he arrived April 6. He proceeded from Punta Arenas, about April 19, after occupying stations there and at Last Hope Inlet, northward to Gallegos and Puerto Deseado; the special eclipse program was carried out on May 29, 1919, at the latter place. He arrived at Buenos Aires early in July and thence again took up work to the south as far as Puerto Madryn. Unusual floods occasioned some delay in this portion of the work. Returning to the office via Buenos Aires, Mr. Sterling made observatory intercomparisons at the Vassouras Observatory of the National Observatory of Brazil under the direction of Dr. H. Morize. This expedition, completed in October 1919, furnishes valuable data at secular-variation stations and at a sufficient number of new stations to complete, in connection with the previous work of the Meteorological Service of Argentina and of the Carnegie Institution of Washington, the general magnetic survey of the southern portion of South America.

Observer D. M. Wise, with the assistance of Observer Andrew Thomson and incidentally to the program of special magnetic and atmospheric-electric observations at Sobral, intrusted to his party in connection with the total solar eclipse of May 29, 1919 (see p. 290), secured magnetic observations at the following stations: Quixadá,

Iguatú, Fortaleza, Camocim, Sobral, Nova-Russas, Amarração, Papagello, Natal, Pernambuco, and Para, all in Brazil, and at Barbados. Valuable secular-variation data result from the reoccupations at Fortaleza, Pernambuco, Para, and Barbados. Messrs. Wise and Thomson sailed from New York City for Brazil on March 26, and returned to the office August 6.

SPECIAL EXPEDITIONS.

Special observations in accordance with the Department's program for the total solar eclipse of May 29, 1919, were made at the following stations: Cape Palmas, Liberia; Campo, Cameroun; Sobral, Brazil; Huayao, Peru; Puerto Deseado, Territory of Santa Cruz; the observatory near Watheroo, Western Australia; and Washington. Detailed instructions were prepared for making absolute observations of diurnal variation with magnetometers and earth inductors in declination, horizontal intensity, and inclination for some stations where variometers were not available.

Africa.—The work at Cape Palmas, Liberia, was carried out by Director L. A. Bauer and Magnetician H. F. Johnston. After the necessary preparations and purchases of stores and supplemental equipment, the party left England on April 12, arriving at Cape Palmas May 5. The magnetic observations included diurnal variation with absolute instruments in declination, horizontal intensity, and inclination, in full accord with program, on the day of the eclipse and preceding and following it, together with necessary control observations. Complete meteorological observations were made during May 20 to June 5, using an equipment loaned by the British Meteorological Office, through the courtesy of Director Shaw. Special equipment had also been taken from England for the purpose of making atmospheric-electric observations of potential gradient. The unfortunate deterioration and consequent failure of the stock of dry cells, however, prevented the use of the apparatus (no dry cells could be procured at Cape Palmas). Observations of shadow-bands were also undertaken. The meteorological conditions on May 29 were favorable. The party left Cape Palmas for Liverpool on June 8, arriving there June 25. Considerable interest was shown, as well as assistance rendered, by Hon. G. T. Brewer, superintendent of Maryland County of Liberia, and by the officials and citizens of Cape Palmas. For further account, see abstract, page 311.

Successful observations in accordance with the special program, including diurnal variations in declination for the period specified on May 28, 29, and 30, and absolute observations for the three elements on May 26 and 31, were obtained by Mr. Brown at Campo, Cameroun. The work was done in a non-magnetic observing-hut 12 feet square, built of bush timber and palm matting, all fastened with bush rope. Complete 24-hour diurnal-variation series of declination were made

on May 24 to 25 and on June 1 to 2. The weather conditions were such that the Sun was generally visible up to about one-half hour before middle of the eclipse, when the Sun entered a fragment of slow-moving fracto-cumulus cloud.

Australia.—Messrs. Wallis and Parkinson, in addition to the daily variometer records, also secured a series of absolute declination diurnal-variation observations with magnetometer at the observatory near Watheroo.

North America.—The work at Washington was limited to absolute diurnal-variation declination observations, in accordance with the program, on three days, May 28, 29, and 30.

South America.—Complete magnetic and atmospheric-electric observations were obtained by Messrs. Wise and Thomson at Sobral, Brazil. Photographic registration of diurnal variation for declination, horizontal intensity, and vertical intensity were secured on the day of the eclipse and also on 6 preceding and 9 succeeding days, together with the necessary control absolute observations and base-line and scale-value determinations. The photographic trace for declination on May 29 was imperfect because of the development of fungi on the variometer magnet, causing contact with and dragging on the damping-box; fortunately absolute determinations of declination were made with a magnetometer by Mr. Wise at minute intervals over the specified period during the eclipse. The special atmospheric-electric observations were carried out with the conductivity and potential-gradient apparatus supplied. It should be noted that the batteries of silver-chloride dry-cells used for the atmospheric-electric work were found particularly well-suited and suffered practically no deterioration because of the tropical conditions encountered. The weather conditions were favorable for viewing the corona during totality, though clouds had obscured the Sun during most of the first phase of the eclipse. The party is particularly indebted to the Brazilian Government for the generous assistance given at Sobral through Dr. H. Morize, Director of the National Observatory at Rio de Janeiro.

Dr. H. M. W. Edmonds, with the assistance of Assistant Observer Rosemberg, obtained at Huayao, near the proposed site of the Peru Observatory, on May 28, 29, and 30, absolute observations of diurnal variation in declination and inclination with magnetometer and earth inductor, in accordance with the eclipse program, and photographic registrations, from May 25 to June 12, with variometers in declination, horizontal intensity, and vertical intensity. The necessary base-line and scale-value determinations for controlling the magnetograph records were made.

Mr. A. Sterling made diurnal-variation observations in declination with magnetometer in accordance with the special program at his magnetic station, Puerto Deseado, Territory of Santa Cruz, Argentina.

In answer to the circular request sent out by the Department, a large number of magnetic observatories cooperated in carrying out the special program of observations proposed. Thus far data, including for most of the stations values of the three elements, have been received from the following: Agincourt and Meanook (Canada), Antipolo (Philippines), Apia (Samoa), Buitenzorg (Java), Bulawayo (Rhodesia), Coimbra (Portugal), De Bilt (Holland), Dehra Dun (India), Lukiapang (China), Pilar (Argentina), Ponta Delgada (Azores), Rude Skov (Denmark), Tortosa (Spain), Valencia (Ireland).

OBSERVATORY WORK.

The construction of the observatory buildings near Watheroo, in Western Australia, under charge of Magnetician W. F. Wallis, with the assistance of Observer W. C. Parkinson, was so far completed as to permit installation of the variometers and beginning of photographic registration for declination, horizontal intensity, and vertical intensity, on January 1, 1919. The records have been continuous since that time, save for a short period on account of the failure of the clock operating the registering apparatus. Absolute control observations and scale-value observations, together with meteorological observations, have been made regularly. The water and sewage systems, the construction of four 2,000-gallon rain-water cisterns, and miscellaneous construction work were all completed by the end of June. The atmospheric-electric instruments with photographic registration will be ready for installation during 1920, and it is expected that some progress in the development of the earth-current work may also be possible. Mr. Wallis, whose excellent and faithful work during a service of about three and a half years deserves high commendation, was relieved as magnetician-in-charge in October by Magnetician E. Kidson, formerly captain in the Royal Engineers, and is en route to the office at the close of the year.

Dr. H. M. W. Edmonds, magnetician, who had been relieved of the command of the *Carnegie* at the end of December 1918, to take up the important construction work of the Department's observatory at Huayao near Huancayo, Peru, sailed from New York City for Peru on February 25. Before his departure various preparations were made for the work, including purchases of observatory equipment, non-magnetic hardware, tools, and various construction supplies, and the preparation of detailed instructions and bills of materials. Beginning of the work upon his arrival at Lima was delayed pending the action of a special commission of the Peruvian Government in determining which of two possible routes should be used for a proposed railway, one of which passes within about a mile of the proposed site tentatively selected in 1917 (see annual report for 1917). Dr. Edmonds in the meantime took up preparations to carry out detailed variometer and

absolute magnetic observations at Huayao during the total solar eclipse of May 29; he also made observations to determine the difference in longitude between Oroyo, where a good value of longitude had been determined, and Huayao, the site of the observatory. Following action by the special commission, deciding against the route passing near the observatory, Dr. Edmonds entered into arrangements in July and August to secure the necessary site and to begin construction of the buildings according to the same plans as used for the observatory at Watheroo, Western Australia. To eliminate possible artificial local disturbance caused by changing magnetic condition of sun-baked adobe walls, it was decided to construct the buildings throughout of lumber with non-magnetic fastenings and hardware. Mr. F. G. Rosemberg, a native of Lima, Peru, and a graduate of Syracuse University at Syracuse, New York, and who had taken part in the original search and survey of a site for the observatory, was appointed assistant observer on March 1 and assigned to Dr. Edmonds. Mr. Albert Smith, of the Department's staff, who has had a large experience in the construction of non-magnetic buildings, sailed from New York on June 21, and reported to Dr. Edmonds on July 3. It is hoped that despite the various delays encountered, sufficient progress will have been made before the end of 1919 to insure continuous construction work throughout the rainy season, which begins in December.

During November and December 1918 the atmospheric-electric observatory at Washington continued in charge of the section under the direction of Dr. Mauchly. Experimental work on the improvements, rearrangements of switchboards and connections, and systematization of operation, looking toward observatory use, were continued. The work was transferred to the Division of Experimental Work on January 1, 1919, under Dr. Mauchly's charge as chief of the section of terrestrial electricity in that division. Prior to the transfer, battery installations to eliminate the experimental nature of some of the apparatus were redesigned and replanned, and conductivity apparatus No. 5 was remodeled and reinstalled by December 20.

General instructions for the installation and operation of variometers and registering apparatus and for the mounting of quartz fibers and forms for standardization of magnetic work at the observatories were prepared. It was decided, in view of experiments (see annual report for 1918, p. 239), to provide transparent glass plates with suitable scales engraved on the under sides for the scaling of observatory traces. This method of scaling gives the mean area of the trace for the hour concerned and is superior to the old method of making the scaling of a central ordinate at each hour.

Additional observatory intercomparisons were obtained during April 1919 by Observer F. Brown under the direction of Dr. Bauer at Kew and Greenwich, and during September 1919 by Observer Sterling

at Vassouras, Brazil. The publication of the results of these intercomparisons must be deferred until the final determinations of corrections, on international magnetic standards at Washington after the return of the instruments used in the comparisons.

Upon the request of the director of the Batavia Meteorological and Magnetic Observatory, three hygrographs and two hygrograph clocks were purchased at the expense of that observatory and forwarded to it.

CONSTANTS AND STANDARDIZATIONS AT WASHINGTON.

Observations, computations, and compilations to determine the constants for the instruments in use and their corrections on international magnetic standards,[1] as determined by comparisons both at the office and in the field, were kept current. The intercomparisons and standardizations included those for all the instruments to be used on the proposed Cruise VI of the *Carnegie* begun at Washington, October 9, 1919. Simultaneous comparisons of instruments for the determination of constants and corrections were made for 8 magnetometers in declination and horizontal intensity, and for 7 dip-circles and for 5 earth-inductors in inclination; corrections in declination were also determined for the compasses of 7 dip-circles, for marine collimating compass No. 1 and for deflector No. 5. Intensity constants were determined and calibrations made for sea dip-circle No. 189 and T. M. compass variometers Nos. 2 and 4.

The investigations relating to the sources of error in terrestrial-magnetic instruments and to the causes for apparent changes of instrumental constants were resumed. The compilations of data for distribution coefficients and temperature coefficients for the different instruments were completed for all of the observations made at Washington, and progress on the corresponding computations and reductions for field observations is now well under way. The results obtained under various conditions and in different fields indicate that the distribution coefficients of a given instrument are practically constant, certainly for long periods, and that deviations from the mean values for individual determinations are in general of an accidental nature. The weighings of magnets with stirrups and determinations of inertia and of induction coefficients for various magnetometers were continued. For a few magnetometers where the corrections on standard determined before and after field work differed materially, the investigations showed that the changes had been caused by alterations in the moment of inertia of the long magnet and its suspension.

Construction of a sine galvanometer for the absolute determination of magnetic horizontal intensity, and hence superior control of future calibrations, was begun. The general design, as developed by Dr. Barnett, is based on the use of two coils arranged as in the Helmholtz-

[1] See Res. Dep. Terr. Mag., vol. II, pp. 270–278.

Gaugain galvanometer (see below); the construction of coils, terminals, and core will be according to the design perfected by the National Physical Laboratory.

Two coils, wound on well-seasoned wood rings, were mounted at one of the stations in the standardizing magnetic observatory, with suitable direct-current circuits and sliding resistances, for the purpose of producing different horizontal-intensity fields for the calibration and testing of variometers. These coils are about 1.8 meters in diameter and are spaced a distance apart equal to their radius on a non-magnetic frame arranged to permit vertical adjustment of the center of system to any height between 8 cm. and 25 cm. above the top of the pier. This adjustment makes possible the testing of any instrument the essential magnetic unit of which is within 8 cm. to 25 cm. of the supporting base.

WORK OF DIVISION OF EXPERIMENTAL WORK.

MAGNETISM.

Improvement in the design of a sine galvanometer.—This instrument, whose construction has been begun, has been designed to give, with much less expenditure of time than that necessary with magnetometers, a precision greater than that obtainable with them or with other sine galvanometers or other electrical devices hitherto constructed for the purpose. The essential parts of the instrument are the coils, the magnetometer, and the circle, together with their adjuncts.

The coils, arranged as in the Helmholtz-Gaugain galvanometer, are to be wound on the best white statuary marble. Each coil will consist of an exact integral number of turns of thin bare copper wire wound under tension in a single layer in a lathe-cut spiral groove. Each coil will be wound in halves for insulation testing. The design is such that it should be possible to determine the constant of the coils to 1 part in 37,000 at least. The error due to a radial displacement of the magnet by even 5 mm. would be only 1 part in 20,000, and that due to an axial displacement of 1 mm. would be about 1 part in 40,000.

The magnetometer will be a simple one, with small, flat steel magnet-mirror, marble house, and quartz suspension. Two circles are provided, both of large diameter and one of them finely divided. The error from circle reading can probably be made not greater than 1 part in 40,000 or 50,000. The electrical measurements can be made with adequate precision, probably to 1 part in 30,000.

The instrument is to be used both in the usual way and also in the way recently proposed by Schuster (Terr. Mag., 19, 1914, p. 19).

Investigation of certain aspects of crystal magnetization.—Three pieces of apparatus have been designed and for the most part completed for this work, but the difficulty of getting suitable material has prevented useful results from being obtained. The most important part of the

work can not be done until suitable paramagnetic crystals are prepared, but with an apparatus soon to be completed, some related work can be done in the very near future.

Investigation of the effects hitherto studied under the caption of magnetphotography.—A somewhat extended investigation has been made under definite and controllable conditions, and evidence has been obtained against any effect of the magnetic field. An abstract of this work is given on pages 304–306.

Investigation of the rotation produced by magnetization and magnetization produced by rotation.—Experiments with iron and nickel have shown the rotation effect looked for, but with disturbances too great to make useful measurements possible. Lack of mechanical assistance and difficulty in getting material have made progress extremely slow. It is hoped ultimately, with apparatus now in course of construction, to get satisfactory results with iron, nickel, and cobalt.

Further preparations have been made for the experiments on magnetization by rotation, to be performed in the Experiment Building. In connection with this work, a special fluxmeter is in process of construction. It is possible that this instrument can also be made useful in measuring the changes in horizontal and vertical intensities. It is hoped to install this apparatus before long in the experiment building.

Report on electromagnetic induction.—This report was prepared for and presented at the Cornell University Physics Conference and Reunion held in connection with the semi-centennial celebration, and will be presented at the coming joint meeting of the American Physical Society and the American Institute of Electrical Engineers. (See abstract, p. 306.)

Course of 26 lectures on theories of magnetism.—This was given weekly, with certain interruptions, at the Laboratory, between September 30, 1918, and June 9, 1919.

Those chiefly engaged on the above researches were: S. J. Barnett (chief of division), D. M. Wise, and C. A. Kotterman.

Apparatus for determining the acceleration of gravity at sea, by S. J. Barnett and H. R. Grummann.—With the hope of producing, if possible, an apparatus for the precise determination of gravity at sea, all the methods hitherto proposed were examined, with the result that the constant-volume, constant-temperature, gas-thermometer method was fixed upon as being the most promising. Various modifications of this method have been used by Mascart, Hecker, Briggs, and Duffield. The apparatus of Duffield, which has the advantages of approximate independence of minute temperature variations and of a possible considerable magnification of sensitiveness, was adopted with certain modifications, partly suggested by Duffield, and partly suggested by Schuster on the basis of an elaborate theoretical study. A tube of this design has been constructed from glass of a kind largely free from after-

action. It is proposed to fill this tube with an inert gas, above the mercury, and to study its behavior under various conditions of motion in the laboratory, and at the levels of the laboratory and the bottom and top of the Washington Monument, before making any attempt to use it at sea.

TERRESTRIAL ELECTRICITY.

The Director's letter announcing the formation of the Section of Terrestrial Electricity to begin with the current year stated that the term terrestrial electricity, as there used, was intended to include (*a*) atmospheric electricity, (*b*) earth currents, and (*c*) polar lights. In the time which has elapsed since the formation of this special section, it has not been possible to devote any time whatever to the last named of the above subjects, and only a very limited amount could be given to subject (*b*). The reduction and publication of the atmospheric-electric observations made at Lakin, Kansas, last year, the necessary provisions for the atmospheric-electric work of the Department's eclipse station in Brazil, various matters concerned with plans and equipment for the atmospheric-electric work aboard the *Carnegie* on her forthcoming cruise, and the operation of the atmospheric-electric observatory on the deck of the laboratory, have occupied practically the entire time of the very limited personnel thus far available, viz, S. J. Mauchly, chief of section; A. Thomson, C. A. Kotterman, and T. C. Kiesel, occasional assistants.

Lakin Eclipse Observations of June 8, 1918.—The first task assigned to the section was the reduction and preparation for publication of the results of atmospheric-electric observations made at Lakin, Kansas, in connection with the total solar eclipse of June 8, 1918. Because of the work necessary to enable the Department to supply atmospheric-electric data to the United States Signal Corps during the autumn of 1918, and also on account of the subsequent overhauling and improvement of the equipment in the deck observatory, it was impossible to begin this work until January.

Perhaps it should be stated that most of the atmospheric-electric equipment available for use at Lakin was either of the laboratory type or at least better suited for laboratory than field work. This caused both the observational and reduction work to be much more extended and laborious than would otherwise have been necessary, in order that the final results should justify the expense and time of the expedition itself.

The results of the Lakin atmospheric-electric observations appeared in the March and June 1919 issues of *Terrestrial Magnetism and Atmospheric Electricity*. In addition, a report on the conductivity and potential-gradient observations was given by Dr. Mauchly before the Philosophical Society of Washington on February 15. (See abstract, pp. 307–308.

Brazil Eclipse Expedition, 1919.—The program of the atmospheric-electric observations made at Sobral during the total solar eclipse of May 29, 1919, was prepared, together with the instructions, and the required instrumental equipment was assembled and tested. A special form of insulator to meet the tropical conditions of humidity and insect life was designed for supporting the ionium collectors used in connection with the potential-gradient observations. This insulator was constructed in the Department's instrument shop and proved, in operation, to be very satisfactory.

Carnegie Atmospheric-Electric Work for Cruise VI.—A careful study was made of the various official reports and correspondence relating to the atmospheric-electric work of Cruises IV and V to secure a proper basis for such modifications and repairs as could be made in the available time. An attempt has been made to eliminate all avoidable difficulties to the end that the observer should have more time and energy to cope successfully with those difficulties which are inherent and unavoidable. A great advance in this direction results from the newly-installed storage battery, which furnishes the power for driving the fans of the conductivity apparatus and the radioactive-content apparatus. This will do away with the periodic renewal of the primary battery which has heretofore been necessary.

It has long been felt that one of the most troublesome problems associated with atmospheric-electric work on shipboard is that of suitable potential batteries for the various instruments. This is especially true where the observations between ports sometimes extend over several months, as is the case on the *Carnegie*. For reasons which have been pointed out by Swann (*Researches Department Terrestrial Magnetism*, vol. III, p. 378), the Krüger batteries have not been found very satisfactory. Throughout most of Cruises IV and V batteries composed of ordinary flashlight cells were used. These proved to be much superior to batteries of the Krüger type, but for the work under consideration are open to two serious objections: (*a*) although the internal resistance is initially low, it increases rather rapidly with age, thus introducing the very difficulties which render the Krüger type unsatisfactory; (*b*) these batteries are constructed for use in flash-lights, and are therefore not designed for longevity. Experience both aboard the *Carnegie* and in the atmospheric-electric observatory at Washington has shown that, owing to the corrosion of the zinc element of the battery from within, very frequent renewals are required in order to have a satisfactory service. As noted in the Director's annual report for 1918, page 239, experiments have been in progress with batteries composed of chloride-of-silver dry cells. These batteries have now given satisfactory service for more than a year in the atmospheric-electric observatory at Washington, and were used with entire satisfaction in connection with the atmospheric-electric observations at Lakin last year and at Sobral

this year. Hence, it was decided, on the forthcoming cruise, to equip the atmospheric-electric apparatus aboard the *Carnegie* with chloride-of-silver batteries. As supplied to the *Carnegie*, each battery unit consists of 50 cells connected in series. As a precaution against accidental short circuit, each unit also contains a 10,000-ohm resistance coil, while the entire unit is embedded in paraffin as a protection against moisture. Considering our satisfactory experience with this type of cells and the extra precautions observed in mounting them for ship use, it is hoped that their use aboard the *Carnegie* will constitute a considerable improvement.

Each of the instruments in the atmospheric-electric equipment of the *Carnegie* was subjected to a thorough overhauling, which in most cases amounted to reconstruction, in the instrument shop. The suggestions of the various observers have been carefully considered and, together with the results of general scientific and instrumental progress, have been incorporated where possible in the modifications and repairs which have been made. Various tests and standardizations of the *Carnegie's* atmospheric-electric instruments have been made. The most important of these have been the calibration, by the Bureau of Standards, of the air-flow meter associated with ion-counter No. 1, and the comparisons in our own laboratory between the air-flow meter of radioactive-content apparatus No. 4 and the Department's standard meter for air-flows of the magnitude involved. The instructions for atmospheric-electric observations aboard the *Carnegie* were revised and in part rewritten to embody the results of the experience of the last several years and to conform to the various instrumental changes.

Earth-current Work.—No experimental work in this subject has been possible during the current year. The activities therein have been limited to critical reports on several papers submitted for publication in *Terrestrial Magnetism and Atmospheric Electricity*, preparation of letters relating to this subject and the preparation of a "Note on a Possible Explanation of the 'Electric Tide' Observed at Jersey." This note was published in the same journal for June 1919, and an abstract thereof is given on page 316.

Observatory Work at Washington.—The instrumental equipment and arrangement of the atmospheric-electric observatory on the deck was overhauled and considerably modified in the Department's shop during the latter part of 1918, just prior to the establishment of the Section of Terrestrial Electricity. Since then the operating directions for the observatory have been revised on the basis of experience and instrumental modifications. Considerable attention has also been given to the development of forms suitable for recording observatory data.

Both the conductivity and the potential-gradient have been continuously recorded throughout the year, except for an occasional day or part of day when repairs or renovations were needed or under way.

The improvement shown by this record results jointly from the various instrumental modifications referred to above and from the substitution of the chloride-of-silver batteries for those previously employed.

INSTRUMENT AND BUILDING WORK

INSTRUMENT WORK.

The work in the instrument shop during the year may be roughly classified as follows: equipment, 41 per cent; improvements and repairs of instruments, 41 per cent; experimental and survey, 9 per cent; miscellaneous and stock, 9 per cent.

Much of the instrumental work was concerned with the study and design of the T. M. compass-variometer in an improved form for ship work and of an inertia-gimbal system planned to eliminate dynamic deviations and magnetic deviations in instruments on shipboard. Much time was devoted also to consideration and development of the use of this instrument as an intensity variometer suitable for the rapid survey of locally-disturbed regions and in the application of the principle involved to the use of intensity variometers for observatory work.

The improvements and repairs of instruments had to do largely with the overhauling, remaking, and modifying of the magnetic, atmospheric-electric, meteorologic, and miscellaneous equipment needed for the *Carnegie* work. Opportunity was presented for the first time to make careful magnetic tests of sea dip-circles of the type constructed by Dover. It was found that the vertical circle of No. 189 was made of German silver and was polarized. This doubtless explains to some extent the erratic behavior of this dip circle, as indicated by the irregular and large corrections obtained for different needles by comparisons with standardized earth-inductors at stations in different magnetic latitudes. When remaking the dip-circle, a new graduated vertical circle of fine silver, carefully tested and found to be non-magnetic, was supplied.

The observations with the marine earth-inductor have heretofore been made, using a balanced moving-coil marine galvanometer. The unanimous opinion of our observers, borne out by study of the results, has been that the accuracy of resulting values for inclination was limited by the inaccuracies of the galvanometer readings. The difficulty arises apparently from unavoidable change of balance with change in time and temperature and jarring caused by the ship's motion which can not be effectively controlled; much time is lost in the tedious operation of rebalancing. Accordingly, the string galvanometer (see p. 313), designed and built by the Department, was arranged for use with the marine earth-inductor on the *Carnegie*. Since the fiber of the galvanometer is quite fine and its inertia thus practically negligible, it is hoped that the resulting inclinations obtained with the earth inductor

at sea will be of a higher accuracy than was possible with the moving-coil galvanometer.

The experience obtained during the last cruise of the *Carnegie* with the atmospheric-electric instruments indicated as desirable certain improvements and modifications in the instruments, and the substitution of a more reliable source of potential than the dry cells heretofore used. After a careful study by Dr. Mauchly of the various reports made on atmospheric-electric work from time to time by the *Carnegie* observers, suggested modifications in design were undertaken in the instrument shop. The following instruments were overhauled and practically rebuilt, numerous improvements and modifications being effected in each case: potential-gradient apparatus No. 2, ionic-content apparatus No. 1, penetrating-radiation apparatus No. 1, radioactive-content apparatus No. 4, and conductivity apparatus No. 3. The experience with silver-chloride cells in the atmospheric-electric observatory at Washington and in the field at Sobral during the special eclipse observations in May and June 1919, was so satisfactory that it was decided to supply such cells for the *Carnegie* work. Batteries in units of 50 cells with resistance of about 10,000 ohms in circuit, all embedded in paraffin and suitably mounted, were made up. Assistance was rendered in the installation of the atmospheric-electric instruments, the magnetic instruments, and the various gimbal stands and other appurtenances before the initiation of the *Carnegie's* cruise.

Miscellaneous new work included the following: Partial construction of sine galvanometer No. 1 for the absolute determination of horizontal intensity; 18 magnetogram scaling-glasses; extensions to switch-boards in the main laboratory for 14 two-wire and 3 three-wire special direct-current and alternating-current circuits to the experiment building; construction of the special switch-boards for the experiment building; construction of special Helmholtz-Gaugain coils with mounting for varying horizontal-intensity fields when calibrating magnetic-intensity instruments; the design and construction of special switch-board for storage-battery electrical equipment on board the *Carnegie;* and special instruments and apparatus in connection with military work.

The repair work, in addition to that on instruments referred to above, included either remaking or extensive repairs on the following: magnetometers Nos. 1, 10, 14, 24, 25, 28; dip circles Nos. 189, 202, 242; marine earth-inductor No. 3; deflectors Nos. 4 and 5; reversible gimbal-stand; 12 sextants and one prismatic circle; mercurial barometers Nos. 3948, 4177; 3 thermographs and 1 barograph; motion-picture camera; and other numerous small instruments and appurtenances for the *Carnegie*. The machine-tool equipment was kept in order and repaired, and was increased by the installation of a wet and dry grinder, a large drill-press, and a tuyere and blower.

As heretofore, all of the non-magnetic castings were made in our own foundry under the direction of Mr. C. Huff. During the year over 3,500 pounds of strictly non-magnetic castings, including bell-metal, copper, gun-bronze, red and yellow brass, and speculum, were made. Mr. Huff also designed the electric installation on the *Carnegie*, and designed, as well as constructed, the switch-boards for the *Carnegie* and for the experiment building.

The personnel of the instrument shop consisted of Messrs. C. Huff, G. H. Jung, W. F. Steiner, instrument-makers; A. Smith, carpenter and pattern-maker; and J. G. Lorz, apprentice in instrument-making. The quantity and quality of the work turned out is sufficient evidence of the activity of the working force during the year.

BUILDING WORK AT WASHINGTON.

The preliminary plans of the proposed Experiment Building for the special investigations in magnetism of the Division of Experimental Work were given some consideration in January and February 1919. The requirements were (*a*) unusual rigidity and strength, (*b*) non-magnetic construction, and (*c*) insulation against sudden temperature changes. It was decided to adopt a concrete double-wall construction, using brass reenforcement, with a continuous, insulating, dead-air space 2.5 inches thick between the two 6-inch walls; further heat insulation was provided for by double windows and double doors, and by a double ceiling of plaster-board, inclosing a 10-inch dead-air space between purlins and a 1-inch dead-air space between the two layers of plaster-board on the under side of the roof purlins. A site was selected, recommended, and approved in March. Thirteen drawings, covering the details of the building, special electric installations with special switch-boards, switch-board extension in the main laboratory, and various pipe-lines, were completed in April, and bills of materials were drawn up.

Because of the unusual requirements and specifications particularly for non-magnetic construction, it was not possible to secure reasonable contracts for the work, which had therefore to be undertaken by the Magnetic Survey Division. It was impossible even to secure bids for the mill-work, all of which had to be done in our own shop. The rough grading and installation of rain-water drains and connections to the culvert were completed and the finished concrete foundations and floor were in place by April 26. The concrete walls were started March 12 and completed June 14. The steam heating is provided from the main laboratory, the heating plant having been suitably enlarged. Special tests showed that it would be necessary, because of non-magnetic requirements, to use brass pipe in the Experiment Building and to a point not less than 40 feet from the nearest part of it. The radiators are made of brass pipe. The necessary steam, return, gas, hot and cold

water, drain, and air pipe-lines, and lead-incased electric cables from the main laboratory are hung underground in a concrete tunnel sufficiently large to allow alterations and additions in accordance with the future development of the experimental work. Provision is made for 14 complete direct-current circuits between the two buildings, and for 3 alternating-current circuits. The outside dimensions of the Experiment Building are 28 by 53 feet; the inside dimensions are 25 by 50 feet with a clear height below the exposed roof-trusses of 12 feet. The inside of the building is plastered in hard sand finish, while the outside is finished in stucco with exposed aggregate of coarse crushed granite and mica. The sill courses about the building and under windows and the columns at the entrance, all cast in place, are of artificial stone with fine granite-and-mica surfacing.

The Experiment Building was completed and ready for use by the Division of Experimental Work early in October. Much time was required for the construction because of the scarcity of materials and of labor under prevailing conditions.

The Division has also had general charge of the maintenance and care of the main laboratory, Standardizing Magnetic Observatory, foundry, and auxiliary buildings. The necessary extension to the switch-board in the main laboratory to provide for the new circuits to the Experiment Building was mounted in the motor-generator room.

A waiting-room, 8 by 12 feet, was constructed during November and December 1918 at the west corner of Thirty-sixth Street and Connecticut Avenue, to provide shelter for the members of the staff in bad weather.

Tile drains for road drainage were installed and the necessary filling and rough grading for a new roadway between the main laboratory and foundry and stable were completed. The macadamized roadways in the grounds were repaired, having been badly damaged during the heavy hauling incidental to the construction of the Experiment Building.

ABSTRACTS OF PUBLICATIONS AND INVESTIGATIONS.

On determination of position of airplanes by astronomical methods. J. P. Ault. (Presented before the American Physical Society at Washington, April 25, 1919.)

The problem confronting the navigator, either at sea or in the air, is to measure as accurately as possible the altitude of some celestial body such as the Sun, Moon, or stars. From this measured altitude a line of position, a so-called Sumner line, is determined, the observer being located somewhere on this line. If two celestial bodies are available, then the intersection of the two lines thus determined completely fixes the geographic position of the observer. If one object only is available, as for example the Sun, then in order to completely determine a position it is necessary to observe in addition the azimuth or bearing of the body. The altitude, usually measured with some form of sextant, is the angular distance of the body above the horizon. For ocean navigation, the sea-horizon is generally available, but for airplane work some artificial horizon must be provided.

The experimental work carried on by the Department of Terrestrial Magnetism at Langley Field, Virginia, in the development of methods and instruments for determination of geographic position of airplanes by astronomical observations, consisted in making sextant observations in the air, to try out the feasibility of different artificial horizons, and in the study and use of different methods of rapid calculation of the position line. The first apparatus used was a preliminary instrument consisting of a mirror mounted on small gimbal rings with a counter-weight suspended in oil to damp the vibrations. The results obtained with this instrument, using different types of sextants, gave an average error for a single observation of ±25′; the error of a group of 10 observations was ±12′. During the second flight 59 observations were made, giving an average error of ±12′, rejecting only 3 which were obviously in error; all the others were less than 36′ in error.

A more accurate instrument was next constructed by the Department and used in the experimental work at Langley Field. The mirror was made of speculum metal and the gimbals were mounted on steel-ball bearings. The results obtained with this instrument gave an error for a single observation of ±15′ to ±29′ and an error for a group of six observations of ±7′ to ±12′.

Through efforts of the Department a sextant with an artificial level-bubble attachment was secured from Professor R. W. Willson, of Harvard University. With this instrument Dr. H. N. Russell obtained results which gave an error for a single observation of ±12′ to ±21′ and an error for a group of five observations of ±6′. The experience with this sextant showed material improvement over the mirror-and-gimbal horizon, both in ease and convenience of handling as well as in rapidity and accuracy.

After the altitude is measured, the next step is to make the calculations and to draw the position-lines on the chart, or by some method to determine the position of the observations. Several methods were investigated. First, the tables devised by Radler de Aquino, of Brazil, were used, the computation with these tables requiring about 3 minutes and the plotting of the position-line about 2 minutes. These tables are published by the United States Hydrographic Office, Publication No. 200. Second, differentmethods of precalculation were studied. The best of these precalculation methods seems to be that outlined by G. W. Littlehales, where some central position on a chart is taken as the assumed position of the observer and tables are precalculated on this basis. If Lambert's conformal conic projection map is used, the arcs of great circles appear as straight lines and the altitude-intercept may be very large without appreciable error, so that one assumed position may be made to cover a wide extent of territory. Third, an instrument called the "line of position computer," designed and loaned to the Department by Professor C. L. Poor, of Columbia University, was used. This instrument is probably the best that has been devised up to date for calculating the position-line in the air. It is made on the principle of a circular slide-rule; both the altitude and the azimuth can be calculated in less that 1.5 minutes of time and to an accuracy of 2 minutes of arc.

Most of the experimental work in computing and plotting positions in the air was done by using Aquino's methods. With his tables, if both the altitude and the azimuth are observed, a previous knowledge of the dead-reckoned position is not necessary, except to determine the magnetic declination of the place of observation. With the natural horizon an observation was made, computed, and the position-lines plotted in 4.1 minutes of time; the mean error of 4 positions thus determined was ±1′. This gives some idea of the accuracy which can be obtained in making sextant observations where the uncertainty of the horizon is eliminated.

Some experimental work was done also on cloud-and-haze horizons at various altitudes, but the difficulty with such observations is to determine the altitude of the horizontal plane. A dip-measurer was used very successfully to determine this altitude, the results giving an error of ±3′ to ±5′ for a single determination.

During a flight from Langley Field to Washington and return, observations were made with the preliminary artificial horizon, using a small pocket-sextant. On the trip to Washington, which occupied 2 hours, 7 position-lines were determined, each based on 10 observations, and all work of computation and plotting of this line was done in the air without previous preparation, using Aquino's tables. The average time for each position-line, including observations, computations, and plotting, was 9.5 minutes. The average error of each line was ±13′ of altitude. On the return trip, which occupied 1 hour and 45 minutes, 9 position-lines were determined and plotted with an average error of ±17′ of altitude. This increased error was due to the irregularity of motion due to "bumps," the airplane falling 50 feet in a single "bump" quite frequently during observations. The results in a set of 10 observations ranged over 3° at times.

If such results as those just described can be obtained with preliminary apparatus and on small airplanes, it is quite certain that the errors can be materially decreased with more refined instruments and larger airplanes.

As previously mentioned, if only one celestial object is available, such as the Sun, then to determine completely the position the azimuth, as well as the altitude, must be measured. The experimental work along this line was interrupted, but the preliminary results were very encouraging. During the flight when azimuths were first measured, 80 observations were taken and the error of groups of 10 was ±0°.6, the mean error of all being ±0°.3. The mean difference between deviations as determined on the ground and those determined in the air was only 0°.1. These observations were made with an azimuth-card the least graduation of which was 5°, the single degrees being estimated. Some further observations were made by J. A. Fleming of the Department; during his first flight he made 110 observations with the above-described instrument. The average time for 10 observations was 1½ minutes and the probable error of a single determination was ±0°.4.

As to instruments, a light sextant is desirable, but no difficulty was experienced in using the ordinary sextant. A special protractor was designed to facilitate the rapid plotting of the line of position. A chart-holder and navigator's case was designed and constructed by the Department.

Several flights were made at night to determine the practicability of observations on the stars. The results showed that observations could be made at night with the same ease and accuracy as during the day. The advantage of night observations is the possibility of always having two objects on which to observe.

As to results as far as the experimental work was carried out, if two celestial bodies are available for observation, a position should be determined within 20 minutes of time and to an accuracy certainly of ±15 miles. Where only a single celestial body is available and where both altitude and azimuth are determined, the resulting position may be in error from 30 to 60 miles. These figures should be very materially reduced with refined instruments and large, stable airplanes.

Report on the 1918–1919 experiments in magnet-photography. S. J. Barnett.

The experiments of R. Colson[1] and W. J. Russell[2] have shown that objects of zinc, brass, wood, rosin, and many other substances when placed on or near

[1] Comptes Rendus (Jan. 1897).
[2] Proc. Roy. Soc., vol. 61, p. 424 (1897); vol. 63, p. 102 (1898); vol. 64, p. 409 (1899); Phil. Trans. Roy. Soc., B, vol. 197 (1904).

the film of a photographic plate produce images; and the experiments of Russell and others, especially S. Saeland,[1] have furnished strong evidence that the effect on the plate in at least most cases is due to the presence in or on the objects of hydrogen peroxide. It was supposed by E. F. Mace[2] that such images were produced only in a magnetic field; but observations published by Bauer and Swann[3] have confirmed the earlier investigators, who used no magnetic field, and have shown that if the magnetic field has any effect it is only to produce modification in the intensity of the images. If these images were due to the emission of free electrons, the magnetic field might in some cases have an appreciable effect upon them. The field would scarcely be expected to alter the rate of emission of hydrogen peroxide from the objects or the sensitiveness of the photographic plate, though it might affect the distribution of the gas, pulling it into or pushing it out from the stronger parts of the field and thus affecting the photographic images.

When the object on the film is active, a positive image is formed beneath it, the remainder of the plate being less affected or unaffected unless other active materials are present. If the object is not active, and the walls of the inclosure or other objects contained therein are sufficiently active, the film is only partially darkened beneath the object, unless it is too thin, but the film is darkened over the rest of its extent. The two effects are often superposed.

In two experiments made with glass objects in glass bell-jars, by the method used in the Department's former experiments, no certain effect of the field could be detected. The method was then radically altered in order to apply more intense and controllable magnetic fields and diminish the difference between the treatment of the plate in the magnetic field and the plate simultaneously exposed out of the field. Two quite similar vacuum cells were made from brass and copper, corresponding parts from the same stock, to hold the two plates, and they were connected by a long brass tube. One cell was usually placed in the field of a powerful electro-magnet, the other at a distance from the magnet. Instead of using two photographic plates, one plate was always cut in two, and half placed in each cell. The two halves were always developed together. The cells with their contents could be interchanged. The temperature near each cell was measured, and the two temperatures were usually kept nearly the same. The maximum magnetic intensity was much greater than in the earlier experiments, exceeding 6,000 gausses.

In most of the experiments the field was nearly uniform over the film, and the intensity was normal to the plate. Experiments were made in this way with similar objects of copper, brass, glass, zinc, and lead laid upon each plate. In some experiments the brass top of the cell was directly above the film, with nothing intervening except the test objects and more or less air. In other experiments the brass top was lined beneath with a sheet of copper. In still others this sheet was covered with a thin layer of rosin. In some experiments the metal objects were freshly sandpapered on the sides touching the films, so as to give positive images. In others the active state of the objects had disappeared, or nearly disappeared, so that the objects cast shadows, with or without positive effects inside them. Experiments were made at different pressures and with exposures ranging from a few hours to many days, and many good photographs were obtained. The results do not indicate any certain effect of the magnetic field.

[1] Ann. d. Phys., vol. 26, p. 899 (1908).
[2] Sci. Amer., p. 411 (Nov. 4, 1916).
[3] Phys. Rev., vol. 9, p. 563 (1917).

Other experiments were made with single plates in fields intense over a central zone and rapidly diminishing in strength toward the ends. In some the intensity at the center was normal to the plate, in others, parallel. In no case was any variation found in the intensity of the photographic effect. In other experiments only a segment of the copper top, instead of the whole top, was coated with rosin, and only a portion of the plate, partially underneath one end of the rosin, was placed in an intense magnetic field. No effect of the field was manifest.

As would be expected from the nature of these effects, according to the theory of Russell, direct experiments made to see whether a beam of the radiation involved could be produced and be deflected by a magnetic field were complete failures.

A report on electromagnetic induction. S. J. Barnett.

This report discusses briefly the chief fundamental results obtained from the days of Faraday to the present time in studying the electromotive forces ordinarily referred to the domain of electromagnetic induction.

Self-induction is first taken up and the phenomena of self-induction are treated as essentially identical with the phenomena of inertia in dynamics, according to the idea of Maxwell and the idea originally accepted by Faraday. The only recent fundamental progress has been in studying the inertia of free electrons and other ions, and experiments are referred to on this subject.

The motional electromotive force, developed when matter moves in a magnetic field, is next considered, and is derived from Ampère's law on the electron theory. Especial attention is devoted to the motional intensity, and the resulting electric displacement, in insulators, of which nothing has been known until recent years.

The induced electromotive force in fixed conductors and insulators arising from the motion or alteration of other systems is next considered, and is expressed both in terms of magnetic flux and in terms of the general vector-potential, which refers the phenomena back to the motion of electrons without the magnetic field as intermediary. The relations between the induced and motional electromotive forces are discussed, as well as the relation of the electric displacement produced in certain cases to the hypothesis of the fixed ether.

The report closes with a treatment of unipolar induction in both so-called open and closed circuits, including brief descriptions of some of the principal experiments, a discussion of the theories involved, and their application to the unipolar generator.

Results of magnetic and electric observations made during the solar eclipse of June 8, 1918—Concluded. L. A. Bauer, H. W. Fisk, and S. J. Mauchly. Terr. Mag., vol. 24, 1–28, 87–98 (March and June 1919). Washington.

Part 1, being the conclusion of the investigations concerned with the magnetic observations made during the solar eclipse of June 8, 1918, by the Department of Terrestrial Magnetism and cooperating magnetic observatories and universities, summarizes the chief conclusions derived from the magnetic observations as follows:

(*a*) Appreciable magnetic effects were observed during the solar eclipse of June 8, 1918, at stations distributed over the entire zone of visibility and immediately outside. (How much further some of the effects may have extended must be left for future study.) The chief characteristic of the effects took place generally in accordance with the local eclipse circumstances and in general accord with effects observed during previous eclipses. The evidences of a direct relation between the magnetic effects and the solar eclipse

are so numerous as to warrant drawing the definite conclusion that an appreciable variation in the Earth's magnetic field occurs during a solar eclipse. This particular variation is termed here the "solar-eclipse magnetic variation."

(*b*) The range of the solar-eclipse magnetic variation, according to the particular magnetic element, is about 0.1 to 0.2 that caused by the solar-diurnal variation on undisturbed days. The effects are of a more or less complicated character, according to location of observation-station in the zone of visibility. The effects caused during the local eclipse-interval are superposed upon those caused by the continued disturbance of the Earth's magnetic field in the region over which the shadow-cone has already passed. It is thus possible to discern effects having a period approaching that of the local eclipse-interval and others having a period approximately that of the entire or terrestrial eclipse-interval.

(*c*) The general character of the system causing the solar-eclipse magnetic variation is the reverse of that causing the day-light portion of the solar-diurnal magnetic variation. The range of the eclipse variation is comparable with that of the lunar-diurnal variation, and, like the latter, the variation usually consists of a double oscillation during its period of development.

(*d*) The range of the apparent effect on the intensity of magnetization of the Earth during the solar-eclipse magnetic variation, is about equal to that found associated with a 10 per cent change in the solar radiation, as shown by changes in the solar-constant values.

(*e*) The results at the high mountain-station, Corona, Colorado, indicate that the magnetic effects during a solar eclipse may be modified and even intensified by altitude of station, topography, and meteorological conditions. In view of the bearing of these results upon the theory of the solar-eclipse magnetic variation and possibly upon the theory of other variations of the Earth's magnetic field as well, it will be highly desirable in the planning of future eclipse work to include as many mountain-summit stations as conveniently possible.

Part 2 gives a synopsis of the meteorological and miscellaneous observations obtained at the various stations.

Part 3 deals mainly with the atmospheric-electric observations made at Lakin, Kansas, the observing-station of the Department of Terrestrial Magnetism. The apparatus and methods employed are described and various curves and tables are given to set forth the results obtained. The chief conclusions derived from the atmospheric-electric observations during the total solar eclipse of June 8, 1918, at Lakin, located in the belt of totality, at an elevation of 900 meters, on an irrigated, grassy plain, far from either sea or mountains, are summarized as follows:

(*a*) A decrease of about 20 per cent in the value of the potential-gradient at the time of totality and continuing for a period of about 20 minutes thereafter.

(*b*) The short-period fluctuations which usually characterize the potential-gradient and which were very marked both before and after the eclipse were almost totally absent during the period of minimum potential-gradient, namely, during totality and the 20 minutes immediately following.

(*c*) The unipolar conductivities, λ_+ and λ_-, each showed an increase, of the order of 20 per cent, during a period beginning several minutes before totality and continuing until about 30 minutes after totality. Inasmuch as λ_+ and λ_- were similarly affected, the remark concerning them applies also to the total conductivity.

(*d*) The air-earth current-density, as computed from total-conductivity and potential-gradient data, showed a rapid increase for about 10 minutes

According to the method of organization and the interpretation put upon the office of secretary, it is expected that the affairs of the unions and sections, between the triennial meetings of the General Assembly, will be largely conducted by the respective secretaries, as is the case also with regard to the general secretaryship of the International Research Council, to which Professor Arthur Schuster was reelected.

Section.	President.	Vice-President.	Secretary and Director Central Bureau.
a. Geodesy	William Bowie (U. S. Coast and Geodetic Survey.)	Vincenzo Reina (Italian Geodetic Commission.)	Lt. Col. G. Perrier. (Army Geographic Service, Paris.)
b. Seismology	Organization deferred		
c. Meteorology	Sir Napier Shaw (British Meteorological Office.)	A. Angot (French Meteorological Bureau.)	C. F. Marvin. (U. S. Weather Bureau.)
d. Terrestrial Magnetism and Electricity.	A. Tanakadate (University of Tokyo.)	Charles Chree (Kew Observatory.)	Louis A. Bauer. (Carnegie Department of Terrestrial Magnetism.)
e. Physical Oceanography.		H. Lamb (University of Manchester.)	G. P. Magrini. (Hydrographic Office, Venice.)
f. Volcanology[1]	A. Riccò (Observatory Etna, Sicily.)	H. S. Washington (Carnegie Geophysical Laboratory.)	A. Malladra. (Vesuvius Observatory.)

[1] Professor Riccò died since the meeting of the Union, and the position of president of the section has not yet been filled.—L. A. B., Nov. 8, 1919.

At a preliminary meeting of the section on Meteorology, under the chairmanship of Colonel Lyons, in the absence of Sir Napier Shaw, a brief discussion was held with regard to the work of the section. The general opinion was that as the meteorological committee of weather bureaus must necessarily concern itself primarily with official and administrative matters, there would be abundant opportunity for useful work of the section along broad investigational lines. Two general resolutions to the following effect were passed:

(*a*) The hope is expressed that there be appointed a joint committee of the International Astronomical Union and of the Section of Meteorology of the International Geodetic and Geophysical Union for investigational work on solar radiation.

(*b*) That international work in atmospheric electricity, as far as possible, be placed under the direction of a committee nominated partly by the Section of Terrestrial Magnetism and Electricity, and partly by the Section of Meteorology.

The work of section (*d*) (Terrestrial Magnetism and Electricity) could be more completely organized than that of the other sections, as it happened that there were present at Brussels six members of the pre-war International Magnetic Commission of the International Meteorological Committee, viz, Angot (France), Bauer (U. S. A.), Chree (England), Palazzo (Italy), Schuster (England), and Tanakadate (Japan). After the election of the officers on

July 24 and discussion of the status of work of the pre-war International Magnetic Commission, the following eight resolutions were passed:

I. That a committee be appointed to consider the best method of securing an adequate comparison of the magnetic instruments in use in different countries, and to consider as to the best method of measuring the magnetic elements in absolute units.

II. That the Section of Terrestrial Magnetism and Electricity concurs in the resolution of the Meteorological Section that international work in atmospheric electricity should be as far as possible placed under the direction of a committee nominated partly by the Section of Terrestrial Magnetism and Electricity and partly by the Section of Meteorology.

III. That the Section of Terrestrial Magnetism and Electricity would welcome cooperation with the International Union of Scientific Radio-Telegraphy in the investigation of the electric phenomena of the higher atmosphere.

IV. That a committee be appointed on the systematic exchange of magnetic curves.

V. That special committees be appointed from time to time for the investigation and report on specific problems in terrestrial magnetism and electricity.

VI. That the Section of Terrestrial Magnetism and Electricity would welcome cooperation with the International Astronomical Union in investigating the relationships between solar and terrestrial magnetic and electric phenomena.

VII. That the ex-officio members of the executive committee be empowered to elect additional members to serve until the next ordinary meeting of the Union.

VIII. That the executive committee consult with the executive committees of other sections of the Union and report to the general secretary of the Union the amount of funds annually required by the section during the period of the present convention.

The executive committee of the Section of Terrestrial Magnetism and Electricity, on July 25, in order to carry into effect these resolutions, appointed 10 committees, the complete composition of which was deferred until the entrance into the Union of other countries. Thus the committee plan of distribution of international researches in terrestrial magnetism and electricity (atmospheric electricity, earth currents, polar lights, radiotelegraphy-strays, etc.), as adopted by the International Astronomical Union, was also followed in section (*d*) as, in fact, generally in the other sections, as far as they could be organized.

The *objects of the International Geodetic and Geophysical Union* are stated in the official version as follows:

1. To promote the study of problems concerned with the figure and physics of the earth.
2. To initiate and coordinate researches which depend upon international cooperation and to provide for their scientific discussion and publication.
3. To facilitate special researches, such as the comparison of instruments used in different countries.

Some observations of the total solar eclipse on May 29, 1919, at Cape Palmas, Liberia. L. A. Bauer. (Papers presented before the American Astronomical Society at Ann Arbor, September 4, 1919, and before the Philosophical Society of Washington, October 11, 1919).

The author, assisted by Mr. H. F. Johnston, carried out a general program of observational work, mainly geophysical, in connection with the solar eclipse of May 29, 1919, which was total at the station finally selected, namely, Cape Palmas, Liberia. Although totality was to last at this station about 6½ minutes, the astronomers avoided this station in view of its being in the rainy belt. However, for the purposes of the expedition of the Department of Terrestrial Magnetism, it did not matter whether clear conditions would be had or not, since the geophysical effect which was primarily to be investigated, namely, the possible effect upon the Earth's magnetic field, would pass through any clouds. However, as it has turned out, for the third time, although certain astronomers at other places were unfortunate, clear conditions were encountered by our party.

When the author left Washington, it had been arranged that he would occupy, conjointly with Dr. Abbot of the Smithsonian Institution, La Paz, Bolivia, in order that he might simulate there conditions which he encountered at his station (Corona, Colorado), the elevation of which is 12,000 feet, during the eclipse of June 8, 1918. As Dr. Abbot intended to look after the photographic work, the author did not provide himself with special photographic appliances for purely astronomical work. However, upon arrival in England, it was found impracticable to reach a South American station in time for the eclipse; accordingly it was decided to proceed to Cape Palmas, Liberia, instead.

Cape Palmas was one of 5 principal stations at which magnetic and allied observations were carried out by the Department of Terrestrial Magnetism in connection with the solar eclipse of May 29, 1919. Two of these stations, Sobral, Brazil, in charge of Mr. D. M. Wise, assisted by Mr. A. Thomson, and Cape Palmas, were inside the belt of totality. A third station, at Huayao, Peru, north of the totality belt, was in charge of Dr. H. M. W. Edmonds; the fourth station south of the belt of totality, at Puerto Deseado, Argentina, was in charge of Mr. A. Sterling; and the fifth, about 100 miles north of the belt of totality, at Campo, Cameroun, was in charge of Mr. Frederick Brown. Observations were also made at a secondary station, Washington, by Mr. C. R. Duvall.

In addition to these stations, special magnetic observations were made at the Department's magnetic observatory at Watheroo, Western Australia, and at observatories all over the globe, both inside and outside of the region of visibility of the eclipse. Reports have already been received from many of these foreign observatories, indicating that the magnetic conditions were ideal for the detection of a possible magnetic effect of the order to be expected from our previous eclipse magnetic observations.

The observational program at Cape Palmas included the following: magnetic and electric observations; meteorological observations, shadow-band observations; times of contacts, and photographs of the solar corona such as could be obtained with the appliances on hand. This comprehensive program was carried out successfully, excepting the atmospheric-electric work, which, owing to the deterioration of the dry-cell batteries secured in England, had to be abandoned. Fortunately, however, another party of the Department of Terrestrial Magnetism, stationed at Sobral, Brazil, where the British party under Dr. Crommelin was located, carried out a full program of magnetic and electric work.

The slides shown gave a general view of the station and facilities available at Cape Palmas, as also two views taken during totality with a small camera, which showed clearly the remarkable solar prominence of May 29, as well as the pronounced coronal extensions. Through the courtesy of Dr. Eddington, of Cambridge University, it was likewise possible to show a slide made from a photograph secured by him at his station on the Isle of Principe.

The eclipse of May 29 as seen at Cape Palmas was not nearly as dark, in spite of its long duration, as the one of June 8 of last year, as observed by the author at his mountain station, Corona, Colorado, where the latter eclipse lasted but 1½ minutes. There was a marked difference in light, both as seen visually and as shown by the photographs, between the inner corona and the outer extensions.

Although three observers took part in the shadow-band observations, at different points, following even greater precautions than were taken at Corona during the eclipse of last year, no shadow bands were observed at Cape Palmas by the various observers, whereas they were clearly observed at Corona.

A definite indication was again had with regard to the small magnetic perturbation or oscillation which, in accordance with previous experience, takes place

during the period of a solar eclipse. This magnetic effect, and the one which may be shown with regard to the change in the electrification of the atmosphere during the eclipse, are of special interest in connection with the wireless-telegraphy experiments conducted during the eclipse at numerous stations along the coasts of Africa, Europe, and America, under the direction of Dr. W. Eccles, of London. Respecting the latter observations, some interesting results have been received by him, indicating that the distance of transmission of signals sent from Ascension Island, in the South Atlantic Ocean, was increased during the time when the eclipse-shadow was between the transmitting station and the receiving station.

There was a steady slight decrease in temperature from 12^h G. M. T., 0.7 minute after the first contact, to 12.7^h G. M. T., and then a more rapid decrease until 14^h G. M. T., when the minimum temperature of 79.4° F. was reached. This time (14^h) was approximately 0.4^h later than the middle time of totality. The increase in temperature after 14^h was rapid, the maximum 82.7° F. being reached at 14.9^h G. M. T. The hygrogram for May 29 showed the following effect: the humidity, which was 71 per cent at 12^h G. M. T., steadily increased to 78 per cent at 14^h G. M. T. There was a more rapid decrease from 14^h G. M. T. to 15^h G. M. T., when the humidity was 66 per cent. The maximum humidity, therefore, occurred at 14^h, or approximately 0.4 hour later than the middle time of totality. The barogram showed nothing marked during the time of the eclipse.

Note on a string galvanometer for use on board ship. J. A. Fleming. Terr. Mag., vol. 24, 29–32 (March 1919). Washington.

This note describes a string galvanometer constructed in the instrument shop of the Department. It is of the type originally developed by Professor Einthoven, of the permanent-magnet air-damped pattern. The magnetic field is produced by a laminated magnet consisting of 5 permanent horseshoe magnets. The string element is a fine quartz fiber coated with silver or platinum by the method described by Professor H. B. Williams;[1] the fiber is soldered to 2 cylindrical copper lugs mounted in standards capable of adjustment by which the fiber may be centered in the air-gap between the soft-iron pole-pieces. The tension of the fiber is regulated by means of a screw operating through the end-supports on threads of slightly different pitches. The arrangements are such that the fiber of any length between 93 mm. and 120 mm. may be used. Suitable cover plates and caps are provided to exclude dust and air-currents.

The deflection of the fiber produced at right angles to the magnetic field by the passage of a current through the galvanometer may be observed directly on the scale in the eyepiece of a microscope suitably mounted, or by projecting the image of the fiber on a glass scale by means of a beam of light passing through the microscope and an optical condenser and suitably mounted prisms on the opposite side of the instrument. The mounting for the galvanometer is such that it may be set up with the fiber either in a horizontal or in a vertical position.

When used on shipboard it was found that vibrations, for example those from the engine, could be practically eliminated by suspending the galvanometer by strong rubber bands.

Auxiliary tables to facilitate revisions of field magnetic observations. H. W. Fisk.

It has hitherto been customary to complete the reduction of time records to deduce the chronometer rate required for the revision of the oscillation observations. This has often delayed revisions unduly, since the chronometer

[1] On the silvering of quartz fibers by cathode spray, Physic. Rev., ser. 2, vol. 4, pp. 517–521, 1914.

rates may not be obtainable before the completion of an expedition, and it is then often a troublesome process requiring a large amount of time and careful analysis. A table has therefore been prepared giving in a compact form the corrections for rate finally deduced that may be applied to the values of horizontal intensity (H) or magnetic moment (m) first computed on the basis of a zero-rate for the chronometer. These corrections depend only upon r, the chronometer rate, and H, as observed, in accordance with the formula

$$\Delta H = -Hr(1.1574 \times 10^{-5}) \qquad (1)$$

derived as follows: If T represents the time of a single oscillation and ΔT the change in T because of chronometer-rate, we have the differential formula $\Delta H/\Delta T = -2H/T$; and since $\Delta T = Tr/86{,}400$, (1) immediately results. The table as prepared gives the necessary corrections for values of H from 0.02 to 0.40 C. G. S. and for values of m from 100 to 1,000 for chronometer rates between 1^s and 60^s.

Computations of local mean time or azimuth from astronomical observations frequently require slight revision on account of small errors in the latitude which was used. A means of correcting the results directly, without recomputing with the revised latitude, is provided by the use of differential formulæ given in Comstock's Astronomy for Engineers, page 207, as follows:

$$\frac{\Delta A}{\Delta \varphi} = -\sec \phi \cot t; \ \frac{\Delta t}{\Delta \varphi} = -\sec \phi \cot A \qquad (2)$$

A table was prepared giving the value of each of these differential coefficients for various latitudes and for hour-angles (or azimuths) differing by 5° from 10° to 90°, but owing to the fact that the coefficients do not change linearly either with respect to latitude or hour-angle, the double interpolation involved in the use of the table was troublesome and uncertain. A more convenient method was obtained by using a graphical process.

A scale of latitudes was laid off as ordinates and a scale of hour-angles (or azimuths) as abscissæ, and the loci of points, whose functions combined according to the formulæ above gave the same value for the differential coefficient, were plotted. By suitably selecting the values of these coefficients, a family of curves was drawn so distributed as to make the work of interpolation comparatively simple, while giving results to the necessary degree of accuracy.

It will be noted that the two formulæ above are identical, except for the substitution of A for t; it follows, therefore, that one series of curves will serve both for the correction to azimuth and to time or longitude.

Attention must be given to the sign of the correction. In the formula used for the computation of azimuth or time, it is convenient to consider the azimuth of a body east of the meridian as negative, reckoned from the south through the east, and positive when west of the meridian reckoned in the reverse direction. It follows, since the sign of the correction is determined by the cotangent factor, ϕ never exceeding 90°, that when the body is to the east, the sign will be plus when A (or t) is less than 90°, and when the body is west the sign will be minus for values of A (or t) less than 90°; in both cases the sign changes for values of A (or t) greater than 90°.

A new method in navigation. A method for finding any one of the three angles when given the three sides of a spherical triangle or for finding the opposite side when given two sides and the included angle of a spherical triangle. Henry B. Hedrick.

We have from spherical trigonometry

$$\cos c = \cos a \cos b + \sin a \sin b \cos C \qquad (1)$$

In navigation, the complements of the sides, a, b, c, are usually given, as, declination $d = 90° - a$, latitude $L = 90° - b$, and altitude $h = 90° - c$. The angle C included by the sides a and b is the hour-angle t, while the angle A

included by the sides b and c is the azimuth Z. We shall consider two cases: (1) Given L, d, t, to find h. (2) Given L, d, h, to find t. The case, given L, d, h to find Z, may be derived from case 2 by the interchange of d and h throughout.

Formula (1) becomes, then, in navigation

$$\sin h = \sin L \sin d + \cos L \cos d \cos t \tag{2}$$

Substituting in (2)

$$2 \sin L \sin d = \cos (L-d) - \cos (L+d) = \alpha - \beta$$
$$2 \cos L \cos d = \cos (L-d) + \cos (L+d) = \alpha + \beta$$
$$2 \sin h = 2\gamma$$

where $\alpha = \cos (L-d)$, $\beta = \cos (L+d)$, $\gamma = \sin h$, we get

$$2\gamma = (\alpha - \beta) + (\alpha + \beta) \cos t; \quad \text{or} \quad \cos t = \frac{\beta - \alpha + 2\gamma}{\alpha + \beta} \tag{3}$$

Formulæ (3) are convenient for use with the ordinary tables of natural sines and cosines when a computing machine is available for making the one multiplication in case 1 or the one division in case 2.

For use in navigation, where the sides of the spherical triangle usually are large, auxiliary tables have been devised containing certain factors of sines and cosines, thus greatly facilitating the multiplication or division. Multiplying (3) by a factor f_i so chosen that

$$f^i(\alpha + \beta) = 1 + S$$

where S is small, either positive or negative, say numerically less than 0.1 we have

$$2f_i\gamma = f_i\alpha - f_i\beta + (1+S) \cos t; \text{ or, } \cos t = \frac{f_i\beta - f_i\alpha + 2f_i\gamma}{1+S} \tag{4}$$

Four factors are sufficient for observation of the Sun in latitude 60° or less. At present two tables are prepared for observation of the Sun in latitude less than 45°; namely, $f_1 = 0.56804$ and $f_2 = 0.68404$.

Each f_i *table* is in two parts. Part 1 contains $f_i \cos \theta$, which gives $f_i\alpha$ for $\theta = L - d$, and $f_i\beta$ for $\theta = L + d$, and part 2 contains $2 f_i \sin h$. In order to get S directly by the addition of $f_i\alpha$ and $f_i\beta$, 0.5 has been subtracted from each value in part 1. Setting $f_i\alpha - f_i\beta = R$ and $2f_i \sin h = H$ our formulæ become

$$H = R + (1+S) \cos t; \text{ or, } \cos t = \frac{H-R}{1+S} = (H-R)(1+S') \tag{5}$$

where $1+S'$ is the reciprocal of $1+S$. A small table gives ΔS, the numerical difference between S and S' for argument S; S and S' having, of course, opposite signs.

In most cases S need not exceed 3 digits, so that the multiplication can be most easily performed by the author's Interpolation Tables, Publication 245 of the Carnegie Institution of Washington. In the absence of any multiplication table, the product may be obtained by use of an auxiliary table, Table 6, based on the method of quarter-squares.

Table 7 gives cos t for both arc and time. All the trigonometric tables are to a minute of arc and to four decimal places, with the final figures so marked that the even figure in the fifth place may be obtained when required.

The following transformation of the formulæ suggests another slightly different form for the tables, using the versed-sine instead of the cosine.

Substituting in (4) $f_i\beta = 1 + S - f_i\alpha$

we have $$2f_i\gamma = 2f_i\alpha - (1+S)(1 - \cos t); \text{ or, vers } t = \frac{2f_i(\alpha - \gamma)}{1+S} \tag{6}$$

or $$\text{hav } t = f_i[\cos (L-d) - \sin h](1+S')$$

In this form versed-sine t (or hav t) is always positive and only one of the two parts of the f_i-*tables* is required.

Note on a possible explanation of the "electric tide" observed at Jersey. S. J. Mauchly. Terr. Mag., vol. 24, No. 2 (June 1919). Washington.

Since 1916 M. Dechevrens[1] has obtained at Jersey, England, continuous records of the electromotive force indicated by a galvanometer one terminal of which is joined to the pipes of the city gas-system and the other to the pipes of the private water-system of the St. Louis Observatory, whose site is on a hill of considerable elevation above the city.

The diurnal-variation curves unmistakably indicate a connection between the observed electromotive force and the tides of the local harbor. Dechevrens has tentatively suggested that the electromotive force may be induced by the tidal waters cutting across the Earth's magnetic field.

Recent observations at Kew by E. G. Bilham,[2] showing a close connection between the water-level in an experimental well and the tides in the nearby Thames suggest the following as a possible explanation of the effects observed at Jersey:

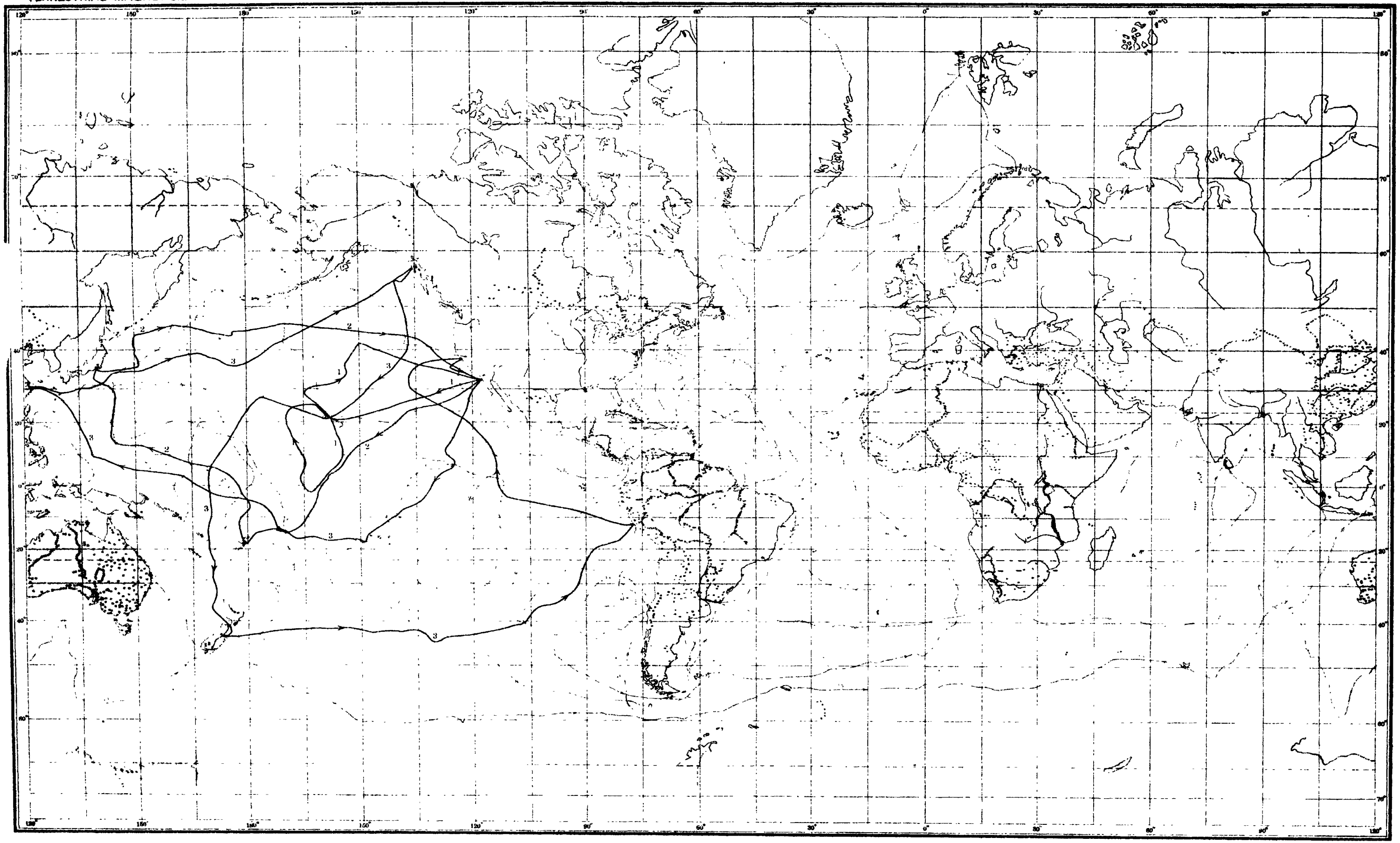
If the normal tides in the Jersey harbor are assumed to cause periodic variations in the height of the local water-table similar to those observed at Kew, then, from the theory of concentration cells, a periodic variation would be a necessary characteristic of the electromotive force between the two pipe systems, provided one system in more accessible to the periodic infiltration of tidal water than the other. Likewise, the successive exposure of differently composed or unequally corroded parts of the lower system might give rise to periodic variations in the electromotive force.

Judgment as to whether the variations of electromotive force resulting from these causes should be considered as accounting for nearly all or for very little of the observed effect must be based upon topographic and geologic details and certain supplementary experiments. If water-table data similar to those obtained at Kew were available for the lower part of the area covered by the gas-pipe system, they would go far toward indicating whether the observed effects should be attributed chiefly to electromagnetic induction or to electrolytic action.

---

[1] See Terr. Mag., vol. 23, pp. 37–39, 1918; Terr. Mag., vol. 23, pp. 145–147, 1918; Comptes Rendus, vol. 167, pp. 552–555, 1918; Terr. Mag., vol. 24. pp. 33–38, 1919.

[2] See Proc. Roy. Soc., vol. 94, pp. 165–181, 1918; Proc. Roy. Soc., vol. 94, pp. 476–478, 1918; Q. J. R. Meteor Soc., vol. 44, pp. 171–189, 1918.



Map showing the Magnetic-Survey Work of the Department of Terrestrial Magnetism during the Period 1905–1912 (October).

(Black lines show the cruises of the *Galilee*, and red ones, those of the *Carnegie*. Red dots show the land stations.)

ARCHEOLOGY.

Morley, Sylvanus G., Sante Fe, New Mexico. *Associate in American Archeology.* (For previous reports see Year Books Nos. 13–17.)

During the month of March 1919, Mr. Morley visited Costa Rica and Nicaragua. The archeological collections in the National Museums at San José and Managua respectively, as well as the larger private collections, were examined, but beyond the ceramic remains no traces of direct Maya influence were found.

The decorative motives in pottery occasionally have elements which resemble the Maya ceramic designs, but as a whole the material cultures of the two countries, judging from the collections examined, show few such resemblances, and we may probably assume that, if felt at all, the Maya influence was but slight.

The Lenca, on the eastern Maya frontier (see Year Book No. 16, pp. 288, 289), and the Pipil, a Nahuatlan people along the southeastern frontier, formed a fairly effective linguistic barrier against a general southeastward extension of the Maya civilization, and although the material cultures of the Lenca and Pipil themselves show a strong Maya influence, particularly in their ceramic art, the original Maya strains had become greatly attenuated by the time such borrowings had been passed on to the tribes of Nicaragua and Costa Rica.

The principal work of the 1919 field season was the excavation in May of Temples 3 and 4 of the Temple Plaza at Quirigua, Guatemala. The excavation of this important group of buildings, no less than the civic and religious center of the site, was commenced 30 years ago by Mr. A. P. Maudslay, at which time Temple 6, on the north side of the plaza, was partially cleared[1] (see fig. 1).

In 1912 Mr. Morley excavated Temples 1 and 2 on the opposite (south) side of the plaza for the School of American Archæology,[2] and in 1914 Mr. Earl Morris cleared the small temple, No. 5, on the west side, and finished Temple 6 on behalf of the same institution.

Through an arrangement with Dr. E. L. Hewett, Director of the School of American Research, Mr. Morley completed the excavation of this group during the present season. A plan of the Temple Plaza, which is 160 feet long by 142 feet wide, and the associated structures is shown in figure 1, and a perspective drawing of Temples 1, 2, 3, and 4 (restored), looking southwest, is given in figure 2.

The excavation of Temples 3 and 4 brought to light no new hieroglyphic texts like those in the doorways and on the cornice of Temple 1,

[1] Biologia Central Americana, Section on Archæology, by A. P. Maudslay, vol. II (text), pp. 5, 6.

[2] "The third season's work in Guatemala," by E. L. Hewett, Bull. Archæol. Inst. Amer., vol. II, pp. 117–134. "Quirigua, an American town 1,400 years old," by S. G. Morley, Scien. Amer., vol. CVII, Aug. 3, pp. 96, 97, 105. "Excavations at Quirigua, Guatemala," by S. G. Morley, Nat. Geog. Mag., vol. XXIV, No. 3, pp. 339–361.

but certain interesting architectural features were uncovered, perhaps not the least of which was the discovery that the old builders had begun to distrust their own handiwork, even in ancient times. Both temples, it was clear from the excavations, had begun to fail structurally before the city was abandoned, particularly at the corners, which had been prevented from sagging only by the erection of heavy buttresses built against the outer walls.

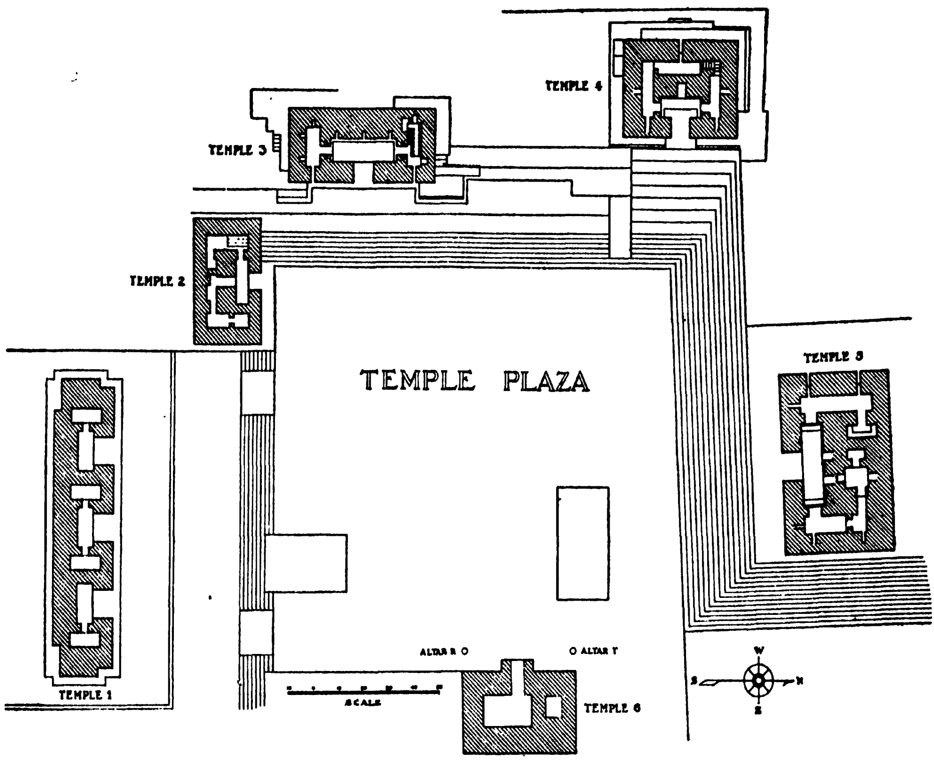


FIG. 1.—Plan of the Temple Plaza and associated structures, Quirigua, Guatemala.

Temple 3 is the better preserved, due to the fact that the level of the terrace upon which it was originally built was subsequently raised at the back and sides to the level of the medial cornice, thus half burying the temple, all save the front, in a solid mass of stone and red clay, the only bonding material used in the Quirigua masonry (see figure 2). This resulted in its being better preserved than Temple 4, as already noted, and permits the establishment of one important architectural fact, namely, that the upper zone above the medial cornice, in this building at least, was vertical and not sloping as in the Palenque temples and the second story of the Monjas at Chichen Itza. Temple 2 nearby has this same feature, and in the restoration in figure 2 all the temples except No. 1 are shown with a vertical wall above the medial cornice.

The façade had been ornamented with an elaborate decoration in stucco which was entirely destroyed when the roof collapsed, many small fragments of which were recovered during the excavation of the terrace in front of the temple.

The plaster on the floors and interior walls was of lime, fairly hard, and had been painted a dark wine-red. Some traces of green were also found in the doorway.

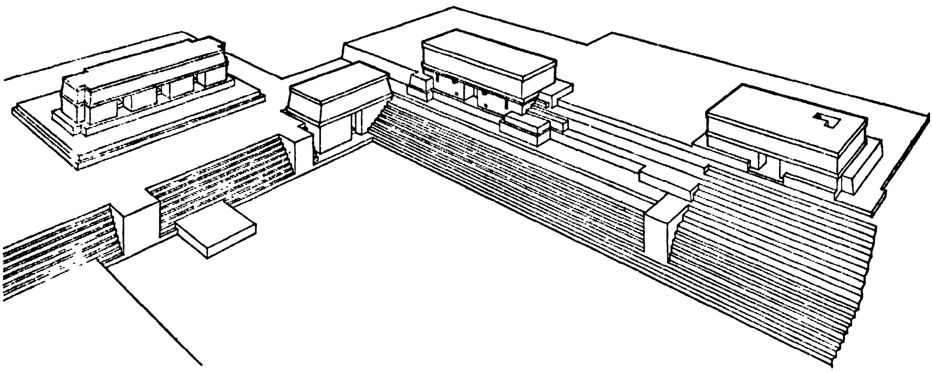


FIG. 2.—Temples 1, 2, 3, and 4, Quirigua, Guatemala, looking southwest (restored).

The most interesting feature of Temple 3 was the small dark interior chamber which was entered by a low passage 3 feet 6 inches high, from the north chamber. It is only 3 feet 10 inches high, 2 feet 8 inches wide, and 4 feet 9 inches long. Strange to say, it was intact when found, every roof stone being in place, and it was half full of red earth lightly packed, as was also the passageway giving access to it. This earth had doubtless washed in since the city was abandoned, and was due to the leaking through of water from above, carrying with it particles of the red-clay bonding material, which gradually filled the chamber. Not a single specimen was recovered from this chamber, the use of which remains problematical.

A similar chamber was found in the excavation of Temple 2 in 1912, and at its farther end were twelve or fourteen rounded river pebbles weighing a pound or more each and showing signs of having been smoked by fire. It has been suggested that these may have been heated and dropped into bowls containing water, thus making vapor, and that the chamber itself was used in connection with some sweating ceremony.

The most important architectural feature of Temple 4 was the interior stairway leading from the northern chamber to the roof. This was composed of two flights of steps and a landing. The first flight is 2 feet 2 inches wide, and has four steps averaging 9 inches in height. Beyond the landing the stairway makes a 90° turn to the left, and then continues 2 feet 8 inches wide for five steps more to the top, the steps averaging 1 foot in height. The roof was gone, but it prob-

ably had been like that over the interior stairway of Temple 20 at Copan, *i. e.*, composed of successively higher sections of the typical corbelled arch roof. The original height of Temple 4 is preserved to within 6 inches at the top of this stairway, from which it may be estimated to have been about 12 feet high.

The specimens found, as is usually the case in temple excavations in the Maya field, were rather meager: a clay-pipe, two shell rings, two jade beads, parts of a very fine alabaster bowl covered with a brilliant red paint almost like an enamel, parts of a human skull found in the doorway of Temple 3, animal and bird bones, many obsidian flakes, a number of broken pottery vessels, and two fragments of a vase showing a band of hieroglyphs carved around the neck just below the rim.

The ground-plans of the several temples in figure 1 show a general similarity in the arrangement of chambers between Temples 1 and 3 on the one hand and Temples 4 and 5 on the other; Temples 2 and 6 being different, not only from either of these two pairs, but also from each other. On the other hand, none of them contained large numbers of chambers, like some buildings elsewhere in the Maya area—for example, the Palace at Palenque or the Monjas at Uxmal; and it is probable that all were used either as temples proper, *i. e.*, places where religious rites and ceremonies were carried on, or for administrative purposes, such as councils, courts, and the like; and finally, probably none of them were dwellings of rulers or priests, such as the Palenque and Uxmal structures mentioned may have been.

The date of erection of the Temple Plaza is not certain, although Temple 2 is clearly the oldest of the six structures surrounding it. The apparent correlation of Zoömorphs O and P, 9.18.0.0.0 and 9.18.5.0.0, respectively, with the northern extensions of the terrace of Temple 5, might indicate that one or the other marks the completion of this part of the group. The dedication of Temple 1, the only one of the six buildings having sculptured decoration, and therefore probably the latest, in 9.19.0.0.0, marks the end of sculptural as well as architectural activity at Quirigua, this site (along with the other Old Empire cities then occupied) probably having been abandoned not long thereafter.

Two trips were made to the ruins of Copan, Honduras, one in December 1918, and the other in June 1919, to secure certain final data for a monograph on the inscriptions of that city (Publication No. 219, now in press). During the course of the last visit, the mound of Stela 7, where the most archaic monuments at Copan have been found, was excavated, disclosing (among other things) a cruciform vault or chamber underneath the foundation-stone of Stela 7, but no new monuments.

Valuable information as to the original provenance of Stelæ 15 and 7 and Altars L′, M′, T, and U was received from the three oldest inhabitants of the modern village, an aged trio between 70 and 80 years of age. The memory of these informants reaches back clearly to 1860;

the oldest was an old lady of nearly 80, whose recollections extend to 1850. All three remember distinctly when the dense tropical forest, described by Stephens in 1839, still filled the entire valley, and when the modern village, now numbering a thousand souls, was composed of only three houses in small clearings in the forest. The information given by these people has proved of great help in checking up the original provenance of the six monuments mentioned.

Before leaving, Mr. Morley installed a small local museum in the cabildo, composed of the fragmentary monuments he has been collecting from the different houses and patios of the village during the past five years. The material left in the new museum comprises the following:

No. 1. Stela 7, two large pieces.
No. 2. Stela 15, two large pieces and one small piece.
No. 3. Stela 22, one medium piece.
No. 4. Stela 21, one small piece.
No. 5. Stela 20, three pieces—one large, the other two medium.
No. 6. Stela 24, one large piece.
No. 7. Stela 25, two small pieces.
No. 8. Fragment E′, one small piece.
No. 9. Fragment Y′, one small piece.
No. 10. Fragment Z′, one small piece.
No. 11. Altar S, complete in one piece.
Nos. 12–24. Fragments V′, thirteen small pieces of archaic stelæ.

The discovery of the meaning of the "winged-Cauac" sign as a variant for the tun-sign, announced in Year Book 17 (see p. 272) is already fulfilling the anticipations there expressed as to its importance in the study of Maya chronology. By means of this sign, it has recently been possible to date a beautifully sculptured peccary skull taken from Tomb 1 at Copan by the First Peabody Museum Expedition in 1892, the inscription and date of which, although unusually well preserved, had long baffled decipherment. By the identification of this new variant for the tun-sign, it is now possible to date the text in question as 9.7.8.0.0 1 Ahau 3 Ceh. This latter is the first contemporaneous date in the Corpus Inscriptionum Mayarum which has yet been found, that may be referred to the katun-ending in 9.8.0.0.0, and fills a previous lacuna in the chronological record at Copan. It is confidently anticipated that this glyph will prove of increasing value, particularly in the decipherment of New Empire texts.

BIBLIOGRAPHY.

Garrison, Fielding H., Army Medical Museum, Washington, District of Columbia. *Preparation and publication of the Index Medicus.* (For previous reports, see Year Books Nos. 2–17.)

The Index Medicus for 1918 (second series, volume 16) contained 776 pages, with an index covering 153 pages, as compared with 682 and 134 pages, respectively, for 1917. During the latter half of the year, many of the large German weeklies became available, and the references to this literature checked the decrease in size of the monthly

numbers apparent throughout the period of the war. The increased percentage of war material necessitated the introduction of many additional subdivisions (*e. g.*, "Aviation," "Cardio-Vascular Diseases," "Evacuation and Transportation of Wounded," "Malingering," "Military Surgery," "Phthisis in Soldiers," "Reconstruction, Reëducation, Rehabilitation," and "Trench Diseases"), under "Military and Naval Medicine." A war supplement of 260 pages, embracing classified lists of the available literature dealing with the medical aspects of the war, was issued in the early fall of 1918.

BIOLOGY.

Mann, Albert, Washington, District of Columbia. *Continuation of investigations and preparations for publication of results of work on Diatomaceæ.*

The present investigations, begun July 1, 1919, were undertaken, because of the increasing importance of these minute aquatic plants and their intimate relationship to several lines of scientific investigation. As the most important of the marine algæ, their biological value has come to be generally recognized, and a consideration of their diversified economic uses indicates that their careful study will be a useful contribution to knowledge. The plan includes several distinct lines:

An illustrated paper is in course of preparation on the marine diatoms of the Philippine and Hawaiian Islands. Although these two possessions of the United States are of similar subtropical location, and both are unusually rich in their diatom flora, they are quite dissimilar in native genera and species. Neither has been previously studied with any thoroughness; a monograph on the diatoms of these localities is therefore desirable. It will include a large number of new species and several new genera.

A similar paper is contemplated on the marine diatoms of the Panama Canal Zone, material for which was secured by the Smithsonian Institution before the waters adjacent to the Atlantic and the Pacific terminals were affected by transfer of species through the opening of the canal. Such a paper promises to be of much value in determining what changes are brought about by commercial intercourse through the canal.

A report will be prepared on some diatom dredgings made in the Antarctic by the Shackleton South-polar Expedition. The material for this report is scanty; for this expedition was one of geographical exploration rather than for the collection of scientific specimens. But any report upon the marine life of this remote region has high value.

A considerable collection of diatomaceous material has been made along the Atlantic seaboard, chiefly in the vicinity of Woods Hole, Massachusetts, and has been partly investigated. This line of work is to be continued. Although its immediate purpose is to supply information for a better understanding of problems connected with the

food-supply of our edible fishes, of which the diatoms are known to form an important part, there is need also for this work in connection with certain oceanographic researches, especially for the purpose of assisting in the determination of the trend and extent of certain ocean currents by means of the particular species of diatoms these currents transport. It is evident that this contributory service can not be rendered until the different diatom floras of the coasts swept by these currents have been carefully studied and recorded. At present our knowledge of the diatoms of our eastern seaboard is very meager, and it ought to at once receive such attention as will bring it to some degree of completeness comparable with that of the shores of Europe. It is hoped that similar studies may include the coasts of the Gulf of Mexico and of the Pacific States, for the diatoms of these regions are even less known to science.

The geological relationships existing between the numerous fossil diatom deposits distributed over the United States deserve the study of a competent diatomist, to supplement the investigations of the technical geologist. A large amount of material is now available for this purpose. It is proposed to take this work up as soon as other lines of research already begun have been completed.

Several of the large and widely distributed genera of diatoms are represented in only a fragmentary way throughout the literature bearing on this subject. This literature is itself rare and difficult of access; and publication of studies of these cosmopolitan genera will be of advantage to this part of marine biological science. It is intended that illustrated monographs will be prepared from time to time along these lines.

It is well to state, in connection with this preliminary report of plans, that the study of these minute and delicate organisms requires a different technique from that of any other line of investigation. Comparatively few scientific students have given to it the time and effort necessary to master it. It happens also that, of the small number who have devoted themselves to this field, an unusually large proportion has recently died. It is consequently opportune that these investigations are now being taken up, and under such auspices as will insure the proper training of new workers who will be fitted to carry forward future investigations in so specialized and uncommon a field of scientific research.

Castle, W. E., Harvard University, Cambridge, Massachusetts. *Continuation of experimental studies of heredity in small mammals.* (For previous reports see Year Books Nos. 3–17.)

The principal subjects under investigation during the past year have been: (1) the phenomenon of linkage in heredity, whereby characters go together or stay apart in genetic transmission; (2) the method of

inheritance of differences in size and its explanation; (3) the action of selection in changing inherited characters.

Five brief papers have been published and one comprehensive paper, Publication No. 288.

My former assistant, Mr. L. C. Dunn, has returned from overseas service and has resumed his interrupted investigations.

Morgan, T. H., Columbia University, New York. *Study of the constitution of the germ-plasm in relation to heredity.* (For previous reports see Year Books Nos. 15–17.)

The following report covers the work of T. H. Morgan, C. B. Bridges, and A. H. Sturtevant for the year 1919 on the constitution of the hereditary materials of the pomace fly, *Drosophila melanogaster.*

The working up of the data concerning the localization of the genes of the third chromosome has occupied much of our attention. New characters have continued to appear, the gene for one of which has increased the length of the third-chromosome map by about one quarter of its former known length. The recurrence of previously known mutations is being carefully watched and checked, because of their bearing on many fundamental problems, such, for instance, as the relative mutability of different loci, the determination of a minimum figure for the number of loci in the germ-plasm of *Drosophila,* and their bearing on evolutionary problems (such as the increased chance of a beneficial mutation becoming established, parallel evolution, etc.).

Attempts to cross *D. melanogaster* with other species have been persistently made, but unsuccessfully so far, with one exception. The causes for this failure, when mating is known to occur, are being further investigated, and new species, when brought into the laboratory, are tried out in all possible combinations. It is hoped to continue this work in other parts of the world where untried species abound. As a preliminary to this sort of work, Sturtevant's taxonomic study of all North American species of this group is nearing completion and will soon be submitted for publication.

It has been found possible to obtain hybrids between *D. melanogaster* and an undescribed species. A yellow mutant in the new species (found by Dr. Metz) furnished an opportunity for a direct test of the supposed identity of mutant characters in the two species. It has been crossed with yellow *melanogaster* and has given yellow hybrids. Both yellows being recessive, it follows that they are in the same locus. This is the first time that parallel mutations in different species have been proven to be identical, though other methods have made this more or less probable in several cases. Even more important in this connection is the peculiar sex ratio in these hybrids and their sterility. Both of these problems are under investigation by Mr. A. M. Brown and others.

Further study of non-disjunction is being carried out on material more favorable than any other hitherto available even in *Drosophila*—

better because of the relatively high frequency of the unusual types of exceptions (primary and "equational").

A new type of chromosome-disturbance, known as "transposition," is being investigated. A piece of a second chromosome has apparently been broken off and then become attached to a third chromosome. Other special problems have also been studied on the *Drosophila* material. Dr. O. L. Mohr, of the University of Christiania, has examined certain questions, the most important being a modification of a region of the sex chromosome that is responsible for the character known as Notch. Miss M. B. Stark has continued her work (at the University of Indiana) on hereditary tumor. Mr. S. R. Safir has practically completed the cytological study of the XO male. Dr. J. F. Nonidez has begun an examination of the normal process of fertilization in *D. melanogaster* and in species crosses. The combined results of all the work done on *Drosophila* is the basis of a book now ready for publication, entitled "The Physical Basis of Heredity."

CHEMISTRY.

Noyes, Arthur A., Throop College of Technology, Pasadena, California *Researches upon (1) the properties of solutions in relation to the ionic theory; (2) the determination of the atomic structure of crystalline substances by X-rays.* (For previous reports see Year Books Nos. 2–17.)

Several investigations have been conducted, with the aid of electromotive force measurements, on solutions of largely ionized electrolytes. The free energy at various concentrations of potassium hydroxid has been determined by Mr. Ming Chow. Mr. Chow has also completed a study of cells of the form H_2, $HCl(c_1)+KCl(c_2)$, Hg_2Cl_2+Hg, in which the total concentration (c_1+c_2) was kept constant. His results lead to the conclusion that, so long as this condition prevails, the respective ions behave as perfectly normal solutes.

Mr. J. A. Beattie has nearly completed an investigation of the free energy of lithium chloride at various concentrations. The measurements were made on cells with and without liquid junctions, and accurate values for the transference-numbers of the salt have been obtained by combination of the results.

Work has also been continued on the determination of oxidation and reduction potentials. Mr. C. E. Ruby has studied the equilibrium conditions of the reaction $3K_2MnO_4+2H_2O=2KMnO_4+MnO_2+4KOH$. Relations between the three higher oxidation stages of manganese have been derived from the results.

The researches on the determination of crystal structure by X-ray analysis has been continued by Dr. D. A. MacInnes and Mr. F. C. Hoyt. Besides the modifications of the Bragg apparatus previously referred to, consisting in the addition of a reference crystal and an

extra electroscope, further refinements of the apparatus have now been worked out which have made possible more accurate measurements of the intensities of the X-ray reflections. A method has also been developed for growing larger, more perfect crystals. A redetermination of the relative intensities of the several orders of reflection has been made for the simplest arrangement of atoms, and work is in progress on the effect on the intensities of the variation of molecular weight in a series of simple crystals (such as those of potassium chloride, bromide, and iodide).

Richards, Theodore W., Harvard University, Cambridge, Massachusetts. *Continuation of exact investigation of atomic weights and other physico-chemical properties of elements and of simple compounds.* (For previous reports see Year Books 2–17.)

On account of the war, investigation in purely scientific matters was almost at a standstill during the early part of the winter. The academic year opened with only one assistant at work in the laboratory in addition to the army officers of the Sanitary Corps who were completing the investigations on the physico-chemical properties of the constituents of cereals, mentioned in the last report. This investigation was completed in November. After the first of January several former students returned from the army, and two new assistants were secured, but so far there has not been sufficient time to permit much finished work. The following investigations have been conducted:

(1) The Atomic Weight of Radioactive Lead from Japan.

Through the kindness of Professor Ikeda, a small specimen of a lead incrustation from a radioactive spring at Hokuto, Japan, was obtained, and Dr. J. Sameshima studied its atomic weight. The sample contained numerous impurities, and the purification of the small amount was difficult. The purest preparation yielded an atomic weight of about 207.13 instead of 207.2, the atomic weight of ordinary lead, showing that this radioactive spring in Japan contains only a small proportion of the isotope of lead which now bears the name of Radium G. The method was essentially the same as that used in previous investigations.

(2) The Purification of Gallium by Distillation as the Chloride.

With the help of Mr. W. M. Craig, this method of purifying gallium salts was carried further, especial attention being given to the impurities which may be present in the initial and final fractions. Further description may well be postponed until the next report, when it is hoped the details will have been more fully studied. Incidentally it was found that one of the best methods of freeing gallium from zinc is by heating the liquid metal in a quartz tube in a high vacuum to a high temperature (over 1000°), when the zinc distils, carrying with it only a very small amount of gallium.

(3) Purification of Gallium by Electrolysis.

Further work with this method, concerning which a hasty preliminary announcement was made in the last report, confirmed the conclusion that gallium may be conveniently purified by careful electrolysis. Nevertheless, unexpected complications arose. The earlier experience, when pure gallium was obtained by the electrolytic process, seems to be possible only when a very small amount of zinc is present (as was the case with the specimen then used). Evidently distilling at a high temperature, mentioned in the preceding section, is more convenient than electrolysis for the elimination of zinc. Indium is eliminated electrolytically without great difficulty. The melting-point of this purest specimen was found to be 29.8° instead of 30.8°, as given by mistake in the last report. Spectroscopic study of these precipitates has been made, but further investigation is still needed for final statement. In particular, the electrode potential of gallium, which we have begun to study, needs careful determination.

(4) The Surface Tension of Liquid Gallium.

The peculiar nature of this element makes all its physical properties of especial interest. Accordingly, with the help of Mr. Sylvester Boyer, the surface tension was studied according to the flat-drop method. The determinations were carried out in an atmosphere of carbon dioxid contained within a glass box immersed in a thermostat at 30°, the liquid flat drops of gallium about 2 cm. in diameter resting on a flat dry-wood surface. Great care was taken to have the optical-glass walls of thermostat and box parallel and vertical. Similar drops of mercury studied in precisely the same way gave a satisfactory standard of comparison. The only doubt as to finality in these results lies in the possibility that in spite of much care to prevent oxidation, the gallium might nevertheless be covered by a film of oxide. The results gave for mercury a surface tension of 44.0 and for gallium 37.2 mg/mm. In the course of this work the densities of the solid and liquid gallium were again measured, confirming essentially the values reported in the last report, only slight deviations being indicated.

(5) The Compressibility of Indium.

In order to fill one of the gaps in the interesting periodic curve relating the compressibilities of the elements to their atomic weights, the compressibility of indium was carefully determined with the help of Dr. J. Sameshima. The method was in principle similar to that used in the earlier researches in this laboratory, but an improvement was introduced which increased considerably the accuracy of determination when working with very small quantities, as in the present case. The density of indium was found to be 7.31, its compressibility $2.7(10^{-6})$, not far from two-thirds that of mercury. This is nearly the value which had been predicted from the general tendency of the curve.

(6) THE MELTING-POINT OF BENZENE, AND THE EFFECT OF COMMON IMPURITIES.

This investigation was a continuation of previous work (see Year Books No. 13, p. 352, and No. 16, p. 300). A yet more careful study of the melting-point of pure benzene was made with the help of Dr. W. C. Schumb. The value 5.494° was found as the mean of many observations on several samples of benzene, using two thermometers standardized in Paris at the International Bureau of Weights and Measures. It was found that when saturated with water, benzene freezes at a point 0.095° lower than when free from water. Hence, in order to obtain an exact value for the freezing point of the pure material, less than 1 per cent of the saturation amount of water must be present. The effect of dissolved air, also, was studied.

(7) STUDY OF CONCENTRATED THALLIUM AMALGAMS.

With the help of Mr. C. P. Smyth, the study of concentrated thallium amalgams (begun with Dr. Wilson and Dr. Daniels) was continued. Further evidence concerning the behavior and constitution of amalgams containing less than 20 per cent of mercury was obtained, pointing to a reasonable explanation for the difference between the electrode potential of pure electrolytic thallium and amalgamated thallium. This investigation was not quite finished and will be continued in the autumn.

Several previous researches were brought to the point of publication and their titles will be found listed in the bibliography.

Sherman, H. C., Columbia University, New York, N. Y. *Chemical Investigation of amylases and related enzymes.* (For previous reports see Year Books Nos. 11–17.)

The work of the year has consisted chiefly in the continuation of the investigations referred to in our last report and the beginning of a somewhat extended study of the effects of amino acids upon the enzymic hydrolysis of starch by different amylases, both in natural and in purified form.

A paper embodying the results of experiments completed last autumn on the influence of hydrogen-ion concentration upon the enzymic activity of three typical amylases was read before the Society for Experimental Biology and Medicine and published in the Journal of the American Chemical Society for February 1919.

The work on the action of amylases and digestive secretions upon starches of different origin, preliminary results of which were outlined in our last report, has been completed and published (Journal of the American Chemical Society, July 1919). Wheat, maize, and rice starches, similarly purified, showed equal digestibility or rate of enzymic hydrolysis. This was true whether the enzyme employed was saliva, commercial pancreatin, purified pancreatic amylase, malt extract, purified malt amylase, commercial taka-diastase, or the purified amylase of *Aspergillus oryzæ*. With all of these, potato starch

showed a rate of hydrolysis equal to or slightly greater than that observed with the cereal starches, except that results were abnormally low in experiments in which purified pancreatic amylase acted upon highly purified alkali-washed potato starch. In this case, however, the addition of a small amount of boiled, carefully neutralized water extract of potato to the digestion mixture resulted in hydrolysis at a fully normal rate. When potato extract was similarly added to dispersions of the starches which had shown normal digestibility, the rate of hydrolysis was increased slightly, not only in the case of purified pancreatic amylase, but also of commercial pancreatin and of saliva. With the amylases of malt and of *Aspergillus oryzæ* no such effect was observed.

The probability that the activation of these enzymes by the potato extract was due to the amino acids and acid amids present and the importance, to our research as a whole, of accurate knowledge of each of the factors concerned in the activation of the amylases, led us to take up, at this time, a careful investigation of the effects of typical amino acids upon amylase action. As yet our experiments in this direction have dealt with aspartic acid and asparagin. Like the water extract of potato, neutralized aspartic acid (neutral solution of sodium aspartate) corrected the abnormally low results observed when purified pancreatic amylase acted upon potato starch which had been purified by washing with very dilute alkali and subsequent thorough washing with specially purified water. It also increased the rate of hydrolysis of all of the starches studied (wheat, maize, rice, and potato) when the enzyme employed was either purified pancreatic or malt amylase, commercial pancreatin, or saliva; but did not increase the activity of a simple extract of malt or of either the commercial or the laboratory preparation from *Aspergillus oryzæ*. Similar results were obtained in experiments in which the enzymes acted upon "soluble" starch prepared by the Lintner method and the amount of reducing sugar formed was determined gravimetrically. This latter method of experimentation was also employed in the study of the influence of asparagin.

The results obtained with asparagin were essentially similar to those described for aspartic acid. Only in the case of taka-diastase was there an apparent slight activation by asparagin and not by aspartic acid, but the difference was very small, possibly within the limits of experimental error.

Many experiments have been carried out with the different enzymes in which both aspartic acid (neutral solution of sodium aspartate) and asparagin were added to the same digestion mixture and in all cases the results have been such as are obtained by the use of an optimum concentration of either of these substances alone. Thus the activating effects of aspartic acid and asparagin are interchangeable rather than additive.

and thus serves to correlate the two series. The standard plants used were wheat, oats, sunflower, and bean. These all gave good results with the exception of oats, which was unsatisfactory in most of the stations, probably owing to the variety selected. The sunflower and bean were especially valuable, due chiefly to the fact that they are widely different in their transpiration and photosynthetic activity. In all the stations weekly weighings were made of the plants and they were consequently maintained in practically the same water-content throughout the period. Some attention was paid to the effect of the size of the container, and it was found that, while larger containers promoted better development, smaller ones were more convenient and lent themselves to a wider range of conditions, particularly in the mountains. It was found necessary to conduct a special series of experiments to test the seals used in the phytometers. The usual wax seals were found to be quite unsatisfactory for field use because of the extreme conditions to be met. Wax sufficiently soft to prevent cracking will not remain solid under the extreme noon-day temperatures, especially in gravel-slides. In the hope of finding a wax seal which would be satisfactory under a wide range of conditions, various combinations of paraffin, beeswax, and petrolatum were tried, in addition to grafting-wax and collodion. The most effective method found was to coat burlap covers, stretched smoothly over the containers, with a wax composed of 5 per cent of beeswax, 5 per cent of petrolatum, and 90 per cent 54° paraffin. When in a semi-liquid condition, the capillary attraction of the burlap fibers serves to prevent the seal from running, while the loose weave of the cloth allows monocotyls to come through as readily as the wax alone.

Photosynthetic Efficiency, by F. E. Clements and Frances Long.

In the endeavor to measure the carbohydrate production of plants in the field and to correlate it with light intensity and water use, further studies have been made in habitats with measured light conditions. These have dealt chiefly with the two major lines of last year, namely, the photosynthetic activity of different species in the same light value and of the same species under different light intensities. The latter appears to exhibit basic correlations with the definite adaptations shown in shade ecads. The efficiency of the leaf at different levels and at different positions in the crowns of trees and shrubs has also received considerable attention. Standard plants in the climax and seral phytometer series have been studied with reference to differences in photosynthetic efficiency at various elevations. It is thought possible that plants may respond to differences in total light intensity that can not be recognized by photometric methods. It is also expected that a more or less definite correlation between photosynthate, transpiration, and dry weight may be discovered in the case

of phytometers. The question of the rate of translocation and its relation to the total carbohydrate present at a particular time has been approached from several angles. Chief among these are the determination of the amount and rate of diffusion into shaded areas of the leaf, and of the relative amount at different times of the day in paired leaves, one of which has had the bundles of the petiole severed to prevent translocation to the stem. Studies have also been made of the comparative efficiency of the leaves of closely related varieties of crop plants, and the results confirm the view that this method will prove of great value in the selection of individuals as well as of varieties for development.

Behavior of Stomata, by G. V. Loftfield.

The investigation of the behavior and efficiency of stomata in a large number of cultivated and native plants has been continued during the summer and autumn, chiefly at the Experiment Station of the American Smelting and Refining Company at Salt Lake City, through the courtesy of the director, Dr. P. J. O'Gara. The major attention has again been centered on the relation of stomatal opening and closing to the efficient factors, and especially to wilting and recovery. Special methods have been devised to show the effect of light and humidity and to check out the errors involved in the use of cut stems. Repeated studies have been made to measure the regulatory action of stomata in transpiration, and particularly in the case of plants wilting naturally and artificially. Special consideration has been given to the amount of decreased transpiration in periodic daily wilting, as well as in plants which fail to recover. Opportunity has also been found to study the absorption of carbon dioxid as determined by the amount of photosynthate made and to ascertain the effect of stomatal movement upon the absorption of sulphurous acid. The results of further studies conform with those already obtained in indicating that most if not all herbaceous species possess stomata with a decisive regulatory action at the time of wilting, even though they show little activity under less severe conditions.

The Ecology of Root Systems, by J. E. Weaver.

The preliminary results of the ecological study of the root systems of grassland species have appeared during the year under the title "The Ecological Relations of Roots." During the present field season the investigation of the root systems of dominants and subdominants of prairies, mixed prairies, and short-grass plains has been greatly extended. The trench or pit method heretofore described has been employed. The examination of roots with reference to their relation to the nature of the soil, the amount and penetration of the water-content, and their competition with each other has been made at 16 stations in the States of Kansas, Colorado, South Dakota, and Nebraska.

Practically all of the dominants of the three major grassland communities have been excavated. Many of these have been checked repeatedly in widely separated areas and under different conditions of soil, precipitation, etc. For example, *Bulbilis dactyloides* and *Andropogon scoparius* have been examined in 8 different stations extending from true prairie to short-grass plains. In addition, the root systems of about 50 subdominant species, thus far unrecorded, have been studied. These include grasses, other herbs, and shrubs. As heretofore, all root systems were drawn to scale or photographed in position whenever this was possible. A systematic study of the root development of certain crop plants, particularly the cereals, was made in the different vegetational regions. Roots of wheat, rye, oats, and barley were examined at 14 stations in the four States, and the correlation of their root development with that of the native vegetation has been established. Upon cultivated areas adjoining the base stations in low and high prairie at Lincoln, Nebraska, the root development of certain grasses, legumes, and composites has been studied. Besides the native species, these included oats, cane, brome-grass, meadow fescue, sweet clover, red clover, sunflower, and others. Here, as at the base stations in the grassland, continuous records of the chief factors influencing growth were kept throughout the season. Correlations between the root development of crop plants and natural vegetation on low or high prairie have been determined.

The character and extent of the root systems were found to be correlated with water-content in nearly all cases. In general, soil type affects root development chiefly through its influence on water-content, in the region studied at least. However, soil texture has a profound effect upon root penetration, and competition was also found to be a primary factor in the control of root development.

Experimental Taxonomy, by F. E. Clements and H. M. Hall.

The transplanting of related species, variable species, and ecads to determine the effect of changed and measured habitats in causing adaptation and variation and in producing new forms has been carried on actively. Approximately 650 transplants of all sorts were made in Colorado and California during the summer and autumn. In each case herbarium specimens and detailed notes were taken of each transplant, and histological material preserved of each species. The transplants are of three types as follows:

1. *Reciprocal transplants.*—These were made between pairs of closely related species or varieties, or between ecads. Forty pairs of reciprocal transplants have been made. Five specimens of each form were transplanted, so that a total of 400 reciprocals is now established. Twelve of the pairs consist of related species to be exchanged between Colorado and California. In these cases the Colorado plants have been

set out in California and the reciprocal transplants will be made next season. The reciprocal transplants made in 1918 are all living, and some of them have already undergone a change in certain characters.

2. *Variation transplants.*—In this case a single form was taken from its natural habitat and transplanted into a series of different environments. About 50 such transfers have been made.

3. *Alpine transplants.*—These are variation or ecad transplants in which the plants are moved from the alpine meadows above 12,000 feet to gardens in the montane or plains climaxes, several thousand feet lower. Approximately 200 plants, representing nearly 100 species, were selected from the alpine communities on Pike's Peak and brought down to the montane zone at Minnehaha, where they were established in two small gardens set aside for this purpose.

Variation and Mutation in Epilobium, by Edith Clements.

The experimental study of the flowers and inflorescence of *Epilobium spicatum* has been unavoidably interrupted, but seeds have been gathered at several localities and grown at Tucson during the winter for the statistical and experimental study of variation and mutation in the rosettes.

Experimental Pollination, by F. E. Clements and Frances Long.

The experimental work with the habits of insect pollinators of a large number of native flowers has been continued throughout the summer. The species studied intensively were *Aconitum columbianum, Capnoides aureum, Delphinium scopulorum, Epilobium spicatum, Frasera speciosa, Geranium richardsonii, Mertensia pratensis, Monarda fistulosa, Pentstemon glaber, P. gracilis, Rosa acicularis,* and *Rubus deliciosus.* The experimental devices employed naturally varied with the type of flower, but they may be illustrated by the cases of *Penstemon* and *Rosa.* In the former the inflorescence was inverted or supplemented by one with pink flowers. The corollas were painted various colors or replaced by paper ones; the tube was slit into separate petals, the outer half cut off, the lower lip removed or the opening variously closed; the anthers and staminode were excised and staminodes and stamens were placed in abnormal positions. In the case of *Rosa,* flowers were reciprocally exchanged with *Rubus deliciosus,* and the competition for particular pollinators studied. In both, flowers were painted or inverted, paper corollas added, stamens removed, and honey or perfume added.

Detailed records of all visitors to various species were made for definite periods, thus showing the number of flowers visited by each kind of insect, the frequency of the visits, the time spent at each flower, and consequently the relative efficiency of the different visitors. Full notes have also been made of the minute behavior of each visitor at the

flower under normal and under changed conditions. The competition of *Rosa* and *Rubus* for pollinators was studied in much detail, the results indicating that *Rubus* is about twice as efficient in its attraction. In a number of flowers, the life histories were again worked out in detail and recorded graphically.

Field and Garden Study of Genera and Species, by F. E. Clements and H. M. Hall.

The general study of taxonomic criteria has been continued in both field and garden. The field study has been chiefly confined to the genera *Chrysothamnus, Artemisia, Atriplex,* and *Haplopappus,* though *Pentstemon, Castilleia, Solidago, Bouteloua, Aristida,* and *Quercus* have received some consideration. A particular endeavor has been made to discover the species of the first four in their type localities, and to determine the various forms as well as the range of variation. Statistical studies have been made of a number of species and it is expected that all will ultimately be included. Special field studies were made at Pike's Peak and in the vicinity of Colorado Springs and Cañon City, and much of the time of the field expedition from Colorado to Oregon and California was devoted to this work. The garden studies of the *Madieæ* were extended by plantings at Tucson, while control experiments were begun on such paired species as *Petalostemon candidus* and *purpureus, Psoralea tenuiflora* and *argophylla,* to determine both their plasticity as to new forms and their reversibility as to each other. Much attention has been given to the details of a taxonomic system which both recognizes and reveals evolutionary relationship, and to a system of nomenclature which will be both usable and attractive.

Climax Formations, by F. E. Clements.

The constant study of the climax formations of the West has made possible the first complete though necessarily summary treatment of them in "Plant Indicators." As in the past, continued attention has been paid in the field to the climax formations and associations, and their successional development. Major consideration has again been given to the formations of widest extent, namely, grassland, sagebrush, desert scrub, and chaparral. The last two were studied more or less intensively at Tucson from October to May, and the grassland and sagebrush chiefly in Colorado and westward to Oregon in the summer and autumn. A detailed investigation was made of the grouping and alternation of the dominants of the *Larrea-Franseria* desert scrub within a radius of 75 miles of Tucson during the winter, and of the dominants of the *Larrea-Prosopis* association in southern New Mexico from May to July. The ecotone between the desert-scrub and grassland was traced in central New Mexico, as well as the transition from the desert plains to the short-grass plains and mixed prairie. This latter association has come to be recognized as the most important of

the grassland formations, ecologically at least, and the equivalence of its dominants, their competitive relations, and their behavior under disturbance, particularly grazing, have thrown a flood of light upon the relations of the several grassland associations. The response of the mixed prairie to grazing is so unexpected and so striking as to explain many popular and scientific errors concerning the prairie and plains during the past century. Moreover, it furnishes the best of illustrations of the essential interdependence of plants and animals in the biotic community, and promises to provide an invaluable key to the great changes of grassland in prehistoric and geologic times.

Climatic Cycles, by F. E. Clements and A. E. Douglass.

The investigation of climatic cycles has progressed sufficiently to permit the publication of a complete summary under the title, "Climatic Cycles and Tree Growth." The further studies of the year have dealt with three additional problems in *Sequoia* cycles as follows:

(1) The doubtful ring 1580A has been studied and promises to indicate a separate year.

(2) Short-period cycles, less than the sun-spot cycle of 11 years.

(3) Gross rings.

Records of the last 500 years were obtained from 12 different trees, carefully selected with reference to topographic location, water-supply, and nearness of other trees. A collection of 15 "rubbings" was made from old weathered pine and fir stumps, nearly all of which show remarkably fine rhythm. One cutting was obtained from a sugar pine that has an extraordinary rhythm and seems to show a relationship to the sun-spot cycle.

In order to test the cyclic growth of trees in other regions, sections of pine, fir, or spruce have been obtained from various localities, such as Pike's Peak, the Black Hills, eastern Oregon, etc. A signal advance in the understanding and interpretation of cycles has come from the recognition of the unique importance of the excess-deficit balance in space as well as in time. While such a balance is of the very essence of climatic cycles, its significance has just begun to be appreciated. It is seen better in the double cycle of 22 years than in the sun-spot cycle of 11 years, but it shows most strikingly in the 2 to 3 year cycle because of the short periods involved. It explains why cycles are often less obvious in humid regions, reconciles the discrepancy between neighboring localities, and harmonizes the marked variations in the rainfall of mountain and plain during the same year. Moreover, there is considerable evidence that the principle of the excess-deficit balance can be applied to the rainfall of the successive months of the year. The study of native vegetation as well as of crop production leaves no doubt that they reflect the cyclic nature of climate, and that this basic effect extends to the animal communities and human society.

Permanent Quadrats, by F. E. Clements, E. S. Clements, and G. V. Loftfield.

The use of permanent quadrats for the study of changes in climatic and successional communities, and of the competition of dominants, especially under grazing conditions, has been much extended during the year. Their ability to afford exact measurements of population changes, and to reveal the degree of equivalence of dominants in terms of physical factors and of competition, gives them essentially an experimental value. In fact, they are the means of measuring and recording the vegetation experiments which are constantly being made in nature by shifting climatic cycles or by various disturbing agencies. While every permanent quadrat yields several sets of results, they are usually established for particular purposes. The general installation throughout the West is for the study of changes of climax vegetation in response to climatic cycles, and the seral movement in primary and secondary succession. A large number of quadrats have been established in grassland to disclose the behavior of climax and seral communities under different intensities of grazing, and to measure changes in carrying capacity. Unusually complete series of quadrats have been located in the desert plains and short-grass plains to permit tracing the effect of rodents upon grassland in detail. In the former community, winter and summer series were necessary, owing to the two vegetative periods. In addition to the quadrat-transect at the Alpine Laboratory, a number have been installed to trace the effects of competition in fir and aspen communities. Quadrats have likewise been employed for a similar purpose in the transplant areas in Nebraska and Colorado, where dominant grasses are brought into competition with the grasses in possession. The climax quadrats have been visited and recharted and additional ones established at Logan (Utah), Bend, Eugene (Oregon), Berkley, Benton, and La Jolla (California), and Seligman, Williams, Grand Canyon, and Tucson (Arizona). The unique value of the permanent quadrat increases with each year's change and the record of it, and it is proposed to summarize the results at intervals of 5 to 10 years.

Quadrat-Transect for the Study of the Biome, by F. E. Clements, G. V. Loftfield, and G. W. Goldsmith.

A permanent quadrat-transect for the complete study and correlation of the habitat with the plant and animal community, or biome, has been established in the montane zone at the Alpine Laboratory. The transect is 860 meters long and 2 meters wide, and includes 6 distinct habitats from the gravel-slide to the subclimax pine forest and the climax Douglas fir forest. A series of three quadrats has been installed in each community. One of these is located in the transect and maintained as a permanent chart quadrat. The other two are denuded after charting, and in one of them the soil is replaced with

gravel to a depth of 8 inches to simulate the original soil conditions of the sere. Simultaneous readings throughout the stations have been made at different levels from time to time of air and soil temperatures, humidity, and light. The readings have been taken at hour intervals for periods of 16 to 18 consecutive hours. The water-content has been determined throughout the summer for each station at different levels. The evaporation has been measured by means of porous-cup atmometers, and sunflower and wheat phytometers have been employed to measure the transpiration, photosynthesis, and growth for each habitat.

The basic purpose of the quadrat-transect is to determine the annual changes of the plant and animal population and to correlate these with primary succession. In addition, it is invaluable for the study of competition and the physiological responses to water and light which are involved in it. The animal population of the several stations has been estimated by various methods. The invertebrates have been counted by using quadrats 4 decimeters square, by sweeping the vegetation for definite periods, and by means of insect traps run simultaneously in the various habitats.

Transplant Quadrats and Areas, by F. E. Clements and J. E. Weaver.

A definite beginning has been made in the application of the methods and principles of experimental vegetation by the establishment of transplant quadrats and areas at Lincoln and Central City, Nebraska, and at Colorado Springs. These have been fenced and equipped with instruments for determining air and soil temperatures, humidity, and evaporation, while determinations of the water-content are made to a depth of 4 feet. The primary objectives of the transplant studies are the comparative equivalence of the dominants of different associations, the conditions under which extral dominants are adopted into the association and the outcome of competition between them. The results will permit the objective determination of the relative importance of migration, physical conditions, competition, and grazing animals and rodents in affecting the invasion of dominants and the permanence of communities. At present, dominants are transplanted as seedlings grown in the greenhouse or as blocks of mature plants. They are planted in areas 0.5 meter square from which the sod has been removed to the depth of 0.5 inch or in tilled areas, and are watered until established. At Lincoln the transplant stations were low prairie, high prairie, and gravel knoll, and both sod and tilled areas were installed in the first two. The species employed were *Andropogon furcatus*, *Elymus canadensis*, *Panicum virgatum*, *Bouteloua racemosa*, *Agropyrum spicatum*, *Poa pratensis*, *Spartina cynosuroides*, *Stipa spartea*, *S. viridula*, *Andropogon scoparius*, *Koeleria cristata*, *Aristida purpurea*, *Bouteloua gracilis*, and *Bulbilis dactyloides*. Moreover, *Andropogon hallii*, *Calamovilfa longifolia*, *Muhlenbergia pungens*,

and *Redfieldia flexuosa* were transferred from the sandhills at Central City to high prairie at Lincoln, and practically all of the prairie dominants of the preceding list were reciprocally transplanted to the sandhills. The majority of these were also transplanted into the mixed prairie at Colorado Springs.

The care taken to secure ecesis has resulted in the growth of the transferred dominants in the majority of cases, but it must be recognized that this is not conclusive as to the origin and constitution of the climax community. The successful transplants demonstrate that the species can grow and reproduce in a new habitat, and at the same time they usually indicate certain differences between the original and the new habitat by the degree of growth and reproduction. Conclusive evidence as to the climax and community position of each dominant must rest upon a complete series of tests from the most decisive, such as merely scattering the seed over the ground, to the planting of seeds, seedlings, and mature plants, protecting seed and plants from rodents and other animals, and watering at critical periods in the life of the seedling or plant. The entire series will also require a definite knowledge of the climatic cycle in order that various tests may be tried during the more favorable years. It seems evident that the use of transplant and seed areas must soon come to be regarded as indispensable for adequate vegetation studies, and especially for the certain recognition of climax associations. In fact, objective and final results as to communities and principles are possible only by such methods. The indicator value of these studies is obvious, and, when crop plants and phytometers are grown in the transplant inclosures, the results are of the first importance for the recognition of climatic areas and for crop production.

Indicator Plants, by F. E. Clements.

The extensive results of several years of indicator study have been brought together in "Plant Indicators," but the intensive results available are still relatively few and scattered. An increase of our exact knowledge depends largely upon instrumental and successional studies, but especially upon phytometer and transplant tests, in which standard plants and dominants are employed as measures and hence as the most accurate of indicators. While the installation of transplant and crop-ecology areas promises much in the way of intensive indicator results in agriculture, it must be recognized that these are to be derived largely as a by-product from the experimental studies of State and National experiment stations and substations. In the case of grazing and forestry, an indicator system of the proper degree of accuracy can only be arrived at from special investigations of the dominants and subdominants of the climaxes concerned. Because it fits in best with other projects under investigation and also promises practical results

of great value, an intensive study of grazing indicators has been begun by means of special fenced inclosures in the various grassland associations. These inclosure fences are adjusted annually in such a way as to show the cumulative effects of grazing and the influence of each year of the climatic cycle. The enormous importance of climatic cycles for agriculture, grazing, and forestry makes cycle indicators matters of the greatest concern, and an especial endeavor is being made to work out an effective system.

Grazing Research, by F. E. Clements, Edith Clements, and G. V. Loftfield.

A comprehensive investigation of grazing has been carried on throughout the year, part of it independently and part in cooperation with State and National agencies. Informal cooperative arrangements of various kinds have been made with many of the State experiment stations, and the majority of these have again been visited for conferences. The cooperation with the Forest Service, Biological Survey, and the University of Arizona in the inclosure study of rodent damage and carrying capacity has been especially profitable. Timely winter rains on the Santa Rita Range Reserve produced a remarkable development of winter annuals, predominantly poppy, *Eschscholtzia mexicana*, but with much *Lupinus sparsiflorus*, *Malacothrix fendleri*, and others. The various inclosures and exclosures graphically revealed the effects of fencing out cattle, and cattle and rodents. The abundance, branching, height, number of flowers, etc., for the important forage annuals were much greater in the cattle inclosures than in the pastures, and somewhat greater in the cattle-rodent exclosures than in the cattle exclosures alone. In fact, such annuals as *Lupinus* and *Malacothrix* were practically eliminated in the pastures. Summer rains likewise brought about the first luxuriant development of grasses for three years, and similarly striking results were obtained in the various fenced areas.

The grass quadrats were charted for the first time since their installation, as the perennial grasses had made practically no growth the preceding summer. Others were located, and the growth was cut at the grazing level to determine the total amount of forage produced' in the endeavor to correlate forage production and the carrying capacity with the wet and dry phases of the climatic cycle. The food habits of the kangaroo rat have been studied intensively, and it has been found that they do most serious damage to the range during the dry phase of the cycle. During wet years the damage done is considerable, as is shown by the large quantities of *Bouteloua* spikes stored in the burrows, but the failure of the grasses to develop spikes in 1918 resulted in the storage of enormous numbers of grass crowns and the complete denudation of considerable areas.

The grazing and rodent quadrats in northern Arizona were visited and charted in both spring and fall, while a considerable number of other permanent quadrats in grassland have yielded much information as to carrying capacity and the effect of the 11-year climatic cycle. The course of the latter has been followed in various regions, and every doubt of its paramount importance in the production of forage and stock has been removed. The effect of the 2 to 3 year cycle is now under investigation, and its importance is already indicated by the behavior of grassland during the past 3 years. The intensive study of grazing indicators is well under way, and it is hoped to work out a practical system for each grassland and scrub association during the field work of the next few years.

Land Classification and Settlement, by F. E. Clements and Edith Clements.

The comprehensive study of indicators during the past 6 years has brought out clearly their basic importance in the adequate classification of land, and subsequent settlement, as shown in "Plant Indicators." Indicator communities not only serve to distinguish agricultural and grazing land from potential or actual forest land, but, what is much more important, they are also invaluable in making it possible to recognize 4 types of land for production, namely, for humid farming, dry-farming, dry-farming and grazing, and grazing alone. Thorough familiarity with the West makes it certain that its proper productiveness and prosperity are impossible until such a land classification has been made. In this connection, a particular effort is being made to distinguish and enumerate prosperous, unprosperous, and abandoned farms and ranches in the various climax regions, to ascertain the causes of failure, and to correlate these with climate and vegetation in such a way as to promote proper classification and to direct successful settlement. The West needs an intelligent land policy above all things, and it is hoped that a detailed knowledge of the economic and social loss involved under present conditions will lead to the desired action by State and Nation. Indicators are also valuable in designating the types of crops as well as the most promising varieties of them for the different regions, and consequently in helping county agents to direct crop production in strict conformity with the character of regional and local climate. Of equally great importance is the recognition of the fact that wet and dry phases of the climatic cycles are practically certain to recur at definite intervals. As a consequence, it is hoped that experiment stations, county agents, and farmers themselves will gradually develop a system of agricultural production in semi-arid and arid regions, which will permit of expansion during the wet phase and contraction during the dry one, together with a cyclic change of crops to fit varieties to the proper phase of the cycle.

Rubber Plants, by H. M. Hall and Frances Long.

The survey of the native rubber plants of western North America has been brought to a close during the year. A portion of the work was undertaken in cooperation with the University of California, and a report on that phase of the investigation has been published. In this report the presence of rubber in 16 species and varieties of *Chrysothamnus* and *Haplopappus* is announced. In addition to the cooperative studies, special attention has been given to native latex-bearing plants and to certain genera of composites. More than 250 species have been investigated and the major number of these has been found to contain rubber in some quantity. In the great majority the amount is too small to be of importance, but in the case of 5 latex-bearing species it is sufficient to indicate their probable commercial value.

In certain species, samples of the plants and latex have been taken at regular periods in order to determine the seasonal variation in rubber content. Studies have also been made of the variation in rubber-content with geographical distribution and ecological conditions, while the amount present in different parts of the plant has been determined in some cases. Experiments have also been made with reference to methods of pollination, formation of seed, and vegetative reproduction from harvested plants. Seeds of *Euphorbia* and *Asclepias* have been planted in field plots at Tucson, Arizona, and Lincoln, Nebraska, and methods of harvesting have been worked out with reference to the conservation of rubber-content. The plots also serve to indicate the probable tonnage of the different species per acre, though they were somewhat too small to make the results conclusive.

GEOLOGY.

Chamberlin, T. C., University of Chicago, Chicago, Illinois. *Study of fundamental problems of geology.* (For previous reports see Year Books Nos. 2–17.)

The principal work of the year has been the preparation of a paper whose purpose is to unify, revise, and extend the main results of the studies that have thus far been undertaken under this grant. In the course of this a special effort is made to bring out into clear definition the dynamic principles and the concepts of force-distribution that have come to be working guides in these studies.

The first part of the paper consists of a review of the work previously done, one purpose of which is to bring into their natural correlations the results so far attained, while another purpose is to show the gradual shift of dependence from static and material considerations to dynamic considerations, together with the growth of reliance upon the latter as the studies progressed. Early in the series of studies it was found indispensable to take into serious account the earth's gravitative sphere of

control and to use it as a basis for the study of the earth's atmosphere, both in respect to its genesis and its maintenance through the geologic ages. In later studies it was found equally indispensable to use this phase of the earth's dynamic envelope as a means of inquiry into the genesis, growth, and maintenance of the earth-body itself. The growth of this basal dynamic concept, and of methods founded on it, does not appear in its real importance in the reports put in print from time to time, and so in this review it is made the thread of the story. In a very similar way, the dynamic encounter of cosmic bodies came to be regarded as a leading factor in the disruption and dispersion of celestial matter precedent to the genetic development of the earth and related bodies, but, as in the previous case, the fundamental and far-reaching functions of dynamic encounter appear only imperfectly in the reports of progress and in the partial publications thus far issued. Not a little misconception of the range and frequency of dynamic encounter appears in even the limited literature that has been called forth on the subject. For this reason the review sets forth with some emphasis such growth of the concept of dynamic encounter as took place in the earlier studies, preparatory to a more comprehensive discussion in the succeeding parts.

The second section of the paper treats in general terms of those phases of the dynamic organization of the earth and of the related cosmic units that are brought under consideration, either directly or indirectly, in the studies under this grant. They are more specifically defined and their range of application extended with a view to more convenient use in the concrete cases later considered and in research generally. The subjects treated embrace: (1) the definite recognition of the distinction between the material organization and the dynamic organization of cosmic units; (2) the dynamic envelopes or fields of force of such cosmic units as require consideration in earth-studies; (3) the electric and magnetic spheres of control that are held to supplement—in certain cases effectively—the gravitative spheres which alone were considered in the earlier studies; (4) the submerged extension of the dynamic envelopes beyond the spheres of control; (5) the central or nuclear dynamic organizations from which the dynamic envelopes spring; (6) certain peculiarities in the distribution of force within the envelopes themselves; (7) the interactions of these envelopes in varying forms and degrees constituting the typical forms of dynamic encounter and rendering them readily visualizable.

The third part consists of a revised treatment of the more essential and especially the more dynamical phases of earth genesis, of earth-growth, of atmospheric maintenance, of basal segmentation, and of other important aspects of the earth's evolution. To find a tenable basis for the interpretation of such fundamental factors of the earth's evolution has all along been the prime object of the whole series of

studies under this grant. It has only been found possible to reach such a basis by means of excursive inquiries into the dynamic organizations and interactions of related cosmic units, but this outer field is left in the main for the next section.

The fourth part of the paper consists of such applications of the properties and of the interactions of the dynamic envelopes of cosmic units, other than the earth, as are either necessarily or helpfully considered in a comprehensive earth-study. In particular, the interactions of the dynamic envelopes of stars, star clusters, and star systems are considered in their relations to nebulous and similar states of partial disorganization out of which the evolutions of normally organized bodies are supposed to grow, and an attempt is made to show that these dynamic envelopes are agencies in the development and in the distribution and localization of nebulæ.

A feature of this section is the discussion of what appears to be a previously unrecognized class of dynamic organizations in which gravitative control is held to be effectively, if not essentially, supplemented by electric and magnetic aid made available by the extreme state of division of the matter composing them, and its interactivity. Comets and nebulæ are discussed as possible types of such peculiar organizations.

The whole ground of the paper has been covered by manuscript, but this lacks completeness and maturity in many parts, while some of the subjects have thus far grown so unexpectedly under study that it is not now possible to say when the paper will be completed.

Vaughan, T. Wayland, U. S. Geological Survey, Washington, District of Columbia. *Study of the stratigraphic geology and of the fossil corals and associated organisms in several of the smaller West Indian Islands.* (For previous reports see Year Books Nos. 13–16.)

No progress report on this project was made for the Seventeenth Year Book of the Institution, because my collaborators and I devoted almost our entire time to work connected with the prosecution of the war during the time the United States was a participant in the world struggle. As soon as possible after the armistice was signed the investigations on West Indian stratigraphy and paleontology were resumed.

During last March the manuscript of a volume bearing the general title "Contributions to the geology and paleontology of the West Indies" was transmitted to the President of the Institution and was accepted for publication as Publication No. 291 of the Institution. It was issued from the press during October of the current calendar year. This volume contains six articles, as follows: "Introduction," by T. W. Vaughan; "Tertiary calcareous algæ from the islands of Saint Bartholomew, Antigua, and Anguilla," by M. A. Howe; "Fossil Foraminifera from the West Indies," by J. A. Cushman; "Fossil Bryozoa from the West Indies," by F. Canu and R. S. Bassler; "Tertiary Mollusca from

the Leeward Islands and Cuba," by C. W. Cooke; "West Indian Tertiary Decapod Crustaceans," by Mary J. Rathbun. During July 1919, there was submitted to the President of the Institution the manuscript of a monograph, "Mollusca of the Bowden marl of Jamaica," by W. P. Woodring.

Two paleontologic monographs have not yet been finished. One of them, on West Indian fossil echinoids by R. T. Jackson, is far advanced toward completion. The other, on West Indian fossil corals, by myself, will require several months' work for its completion. In the paper cited below[1] I have given a summary of all available information on West Indian fossil corals up to July 1917.

The object of these investigations is to help in building a proper foundation for the correlation of the geologic formations in the West Indies and for dating the different events in the geologic history of that region. The following are the ages of the successive Tertiary geologic formations: upper Eocene, middle Oligocene, upper Oligocene (considered by some paleontologists as basal Miocene), lower Miocene, middle and probably upper Miocene, and Pliocene. The status of the reports on the different groups of organisms according to the different geologic horizons is given in the following table:

Status of West Indian paleontologic reports.

Group of organisms and author of report.	Geologic horizon.			
	Upper Eocene.	Middle Oligocene.	Upper Oligocene.	Miocene.
Calcareous algæ, by M. A. Howe	*a*	*a*	*a*	*o*
Foraminifera, by J. A. Cushman	*a*	*a*	*a*	*a*
Corals, by T. W. Vaughan	*b*	*b*	*b*	*b*
Echinoids, by R. T. Jackson	*c*	*c*	*c*	*c*
Bryozoa, by F. Canu and R. S. Bassler	*o*	*a*	*a*	*a*
Mollusca, by C. W. Cooke and W. P. Woodring	*a*	*a*	*a*	*a*
Decapod Crustacea, by Mary J. Rathbun	*a*	*o*	*a*	*a*

a, reports completed; *b*, report in preparation, preliminary summary of faunas published; *c*, report in preparation, no preliminary summary; *o*, not represented in available West Indian collections. Pliocene is not included in the table, as it seems to be known only on the south coast of Cuba.

After the reports above mentioned have been finished, descriptions of local geologic details and a summary account of the geologic history of the West Indies according to present information will be completed as soon as possible. Much of the manuscript of the summary report has been written. Dr. E. O. Hovey, of the American Museum of Natural History of New York, has undertaken to prepare, in collaboration with me, an account of the igneous phenomena of the West Indies.

[1] Vaughan, T. W., Fossil corals from Central America, Cuba, and Porto Rico, with an account of the American Tertiary, Pleistocene, and Recent coral reefs. U. S. Nat. Mus. Bull. 103, pp. 189–524, pls. 68–152, 1919.

HISTORY.

Fox, Dixon R., Columbia University, New York, N. Y. *Completion of the work of the late Professor H. L. Osgood toward an institutional history of the American Colonies during the period of the French wars.* (For previous reports see Year Books Nos. 11–17.)

The nature of the work assigned to me as Research Associate of the Institution is such that only a report of general progress can be made. My task is to prepare Professor Osgood's manuscript for the press. I have worked at this intermittently during the winter and since, and have filled in the notes of about one and one-half volumes. There are many alternative readings to be decided, parts indicated to be changed, copies to check, and all references to be verified. Upon this last Professor Osgood was very insistent, and though the work is not a little laborious for the four volumes, I expect that it, as well as the other necessary tasks, can be done during the coming academic year.

Professor Frank W. Pitman, of Yale University, has about finished a supplementary chapter for the work, entitled "The British system in the West Indies." This will round out Professor Osgood's plan as nearly as we can.

Sarton, George, Washington, District of Columbia. *Associate in the History of Science.*

Dr. Sarton's connection with the Institution began on July 1, 1918. He submits the following in explanation of his work and as a general introduction to his subsequent reports:

The purpose of the history of science is to establish the genesis and the development of scientific ideas, taking into account all the intellectual exchanges and all influences brought into play by the progress of civilization. When increasing specialization is the very condition of success, it becomes essential that at least a few men study the generalities of each branch of science, so as to be able to define clearly the relation of each part to all others. Technicians do not want to know any but the latest results; yet to understand the true meaning of science and to take a broad view of the whole, one must needs look backward and take into account the whole experience of the past. It is only the historian of science who can do this.

To harmonize contentions between scientists on the one hand and men of letters and art on the other, it is necessary to show the inner life of science and its relations to all other human activities, to explain not simply its usefulness, but also its greatness and its beauty. The history of science thus becomes a much-needed link between science and the humanities. It helps us to reconcile the love of beauty with the love of truth, idealism with knowledge. We need both equally.

An immense amount of pioneer work is still necessary to give to the history of science the same completeness and accuracy which have been reached in other investigations.[1]

My work during the first year will be briefly considered under the following headings: (1) Leonardo studies; (2) history of physics; (3) history of science; (4) history of the Carnegie Institution of Washington.

1. *Leonardo studies.*—The greatest part of my time has been devoted to the study of the manuscripts of Leonardo da Vinci. This great artist was also the greatest scientist and engineer of his time, and his interests were universal to such an extent that my study of his papers will lead me to the writing of what might be called an encyclopedia of science and technology at the height of the Italian Renaissance.[2] I am still in the analytical stage of my investigation and have thus far examined and classified the contents of about half the manuscripts. There are dispersed in various European libraries probably about 5,800 pages, of which perhaps about one-fifth is practically unread. This proves sufficiently the great need of a thorough study of Leonardo's writings. A part of these manuscripts (most of them owned by the King of England) contain anatomical drawings and notes which I am not qualified to study, but I have fortunately secured the collaboration of Dr. J. Playfair McMurrich, professor of anatomy at the University of Toronto, who is now investigating them.

2. *History of physics.*—There does not yet exist a satisfactory account of the development of physics, and especially of modern physics. This is the more unfortunate in that physics is perhaps the most central of all sciences. I am accumulating materials for a history of physics in the nineteenth century, my purpose being to treat the subject in a very catholic way, making frequent short excursions into mathematics, chemistry, astronomy, even biology, and also in the engineering and technical arts.

3. *History of science.*—I have given a good deal of time to the establishment of a critical bibliography of the books and papers published on the history of science during the war and to the preparation of No. 6 of *Isis.*[3] I have also continued my activity in behalf of the New Humanism—that is, the reconciliation of science and the humanities—and in this regard I have given two lectures to Professor L. J. Henderson's students at Harvard, one at the Art Association of Montreal, and one at the Fogg Museum of Cambridge, Massachusetts.

---

[1] For further development of these ideas see George Sarton: The history of science, *The Monist*, XXVI, 321–365, Chicago, 1916; Le Nouvel Humanisme, *Scientia*, XXIII, 161–175, Bologna, 1918; The teaching of the history of science, *Scientific Monthly*, VII, 193–211, New York, 1918.

[2] George Sarton: The message of Leonardo; his relation to the birth of modern science, *Scribner's Magazine*, LXV, 531–540, New York, May 1919; Une Encyclopedie Léonardesque, *Raccolta Vinciana*, X, 235–242 Milano, 1919.

[3] George Sarton: The publication of Isis, *Science*, n. s., vol. 49, 170–171, 1919; Letter to the editor of the New York Evening Post, February 22, 1919; The history of science, *Science*, n. s. vol. 49, 497, 1919.

4. *History of the Institution.*—The twenty-fifth anniversary of the Carnegie Institution of Washington will be celebrated in 1926. At that time it will be desirable to look back upon the work that has been accomplished. To give to this retrospective survey real historical value, it is indispensable to consider the Institution, not as an isolated unit, but as a part of the scientific organization of the world, and with this in view I propose to become intimately acquainted with the various departments of the Institution.

At the time of writing (July 1919) I am preparing to sail for Europe, where I shall spend about half a year. The motives of this journey are: (1) to recover some notes and manuscripts left in Belgium and to ship them to Washington, together with what remains of my library; (2) to resume the publication of *Isis* in Brussels and to take the necessary measures to enable me henceforth to edit it from Washington; (3) to carry on sundry researches concerning Leonardo in England (Windsor Castle), in Paris (Louvre), and in Italy (Florence and Milan); (4) to confer with various European scholars whose collaboration I shall need, and to organize our common work in the best manner.

LITERATURE.

Bergen, Henry, Brooklyn, New York. *Research Associate in Early English Literature.* (For previous reports see Year Books Nos. 11–17.)

During the year 1918–19 I have been occupied in passing the proofs of the text of Lydgate's "Fall of Princes" through the press and in preparing a further portion of the "Troy Book" glossary for the printer. I trust that we shall be able to issue the entire text of the "Fall of Princes" before the end of next winter, or earlier, so that I can then give all my time to the completion of the "Troy Book" glossary and to the preparation of the introductory part of the edition of the "Fall of Princes" for the press.

Tatlock, John S. P., Stanford University, California. *Preparation of a concordance to Chaucer.* (For previous reports see Year Book Nos. 16–17.)

The making of the slips for the Chaucer Concordance is nearing completion. Forty people in various parts of the country have been at work on them since early in April, and the finished work is now coming in. During the next year editorial work on them will be proceeding.

MATHEMATICAL PHYSICS.

Moulton, F. R., University of Chicago, Chicago, Illinois. *Investigations in mathematics, cosmogony, and celestial mechanics.* (For previous reports see Year Books Nos. 5, 6, 8–17.)

The greater part of the year was spent in the Government service as major in ordnance, U. S. Army, in charge of the ballistics branch of the Ordnance Department. The duties were (1) the planning and direction of range firing of all the artillery of the U. S. Army, (2) the preparation of range tables for all artillery of the U. S. Army, (3) mathematical investigations in ballistics, (4) the formulation and direction of experiments on artillery problems.

The subject of ballistics was found in a very unsatisfactory state both mathematically and practically. So far as it pertains to the translation of projectiles and the influences of abnormal conditions, it was placed on an entirely new basis. The results of these investigations were issued in confidential blueprint pamphlet form by the Ordnance Department. The titles of the papers written by the author of this report are:

1. On Methods of Computing Trajectories (a collection of nine different investigations).
2. Effects of the Earth's Rotation on the Flight of Projectiles.
3. On the Determination of the Law of Retardation of a Projectile by the Atmosphere from Firings through Velocity Screens.
4. The Second and Higher Order Terms in Differential Variations.
5. Fundamental Theorems on the Solution of Differential Equations and the Logical Basis for the Numerical Solution of Differential Equations.
6. Effects of Variations in the Velocity of Sound on Trajectories.
7. Formulas for Interpolation.
8. General Theory of the Computation of Differential Variations.
9. Curves of Constant Fx' and Fy'.
10. On the Determination of the Law of Retardation of a Projectile by the Atmosphere from Firings through Velocity Screens (second paper).

A summary of all the work was embodied in a history of the Ballistics Branch and was issued in a final report of 91 pages.

In the last few months work has been resumed on periodic orbits, and the manuscript for the final chapter on this work is receiving its final touches.

METEOROLOGY.

Bjerknes, V., Bergen, Norway. *Preparation of a work on the application of the methods of hydrodynamics and thermodynamics in practical meteorology and hydrography.* (For previous reports see Year Books Nos. 5–17.)

The extended Norwegian Weather Service, alluded to in the previous report, has furnished rich material for the investigation of the structure of cyclones and the conditions for the formation of rain. Preliminary reports on the results obtained have been given in Professor Bjerknes's address "Weather forecasting" and in J. Bjerknes's paper "On the structure of moving cyclones," both of which have also been reprinted in the Monthly Weather Review (February 1919). The general results may perhaps best be summed up thus:

The atmosphere is crossed and recrossed by surfaces of discontinuity, separating from each other masses of air having more or less different velocity and different physical properties, showing themselves by differences of temperature and humidity, and, as pointed out by Mr. Bergeron, also by marked differences of transparency. Almost every change of weather is due to the passage of a surface of this kind. The rain falls from the warm air when it is forced to mount the slanting surface separating it from the underlying heavier and colder air. In the cyclones this takes place on a gigantic scale along the "steering surface" and the "squall-surface," as developed in the mentioned paper by J. Bjerknes. But the same play may be recognized also in the phenomena of smaller scale down even to the local showers.

These results give a physically simple and intelligible view of the phenomena of the weather chart and seem promising from a practical point of view. For promoting weather-forecasting it will be of high importance to arrange the observations so that the formation of the discontinuities can be detected at an early state, and their propagation followed as accurately as possible on the weather charts.

NUTRITION.

Osborne, T. B., and L. B. Mendel, New Haven, Connecticut. *Continuation and extension of work on vegetable proteins.* (For previous reports see Year Books Nos. 3–17.)

During the past year our investigations have followed chiefly the direction indicated in the report for 1918. The extensive study of the nutritive value of the wheat kernel there referred to was continued and a detailed account of the results has been published. In connection with this work we were surprised to find that, contrary to the prevailing belief, the water-soluble vitamine of the wheat kernel is not concentrated in the embryo. Although the so-called commercial wheat embryo is much richer in water-soluble vitamine than either the endosperm or the entire kernel, nevertheless, when the *pure* embryos proper were dissected out from the kernels and fed as the sole source of this vitamine with an otherwise adequate ration, even relatively large quantities of them failed to promote any growth on the part of the rats receiving them. Moreover, the kernels from which the embryos had been removed showed no appreciable diminution in their vitamine activity as compared with the undissected kernels. It thus appears that the water-soluble vitamine is located in the endosperm. That it is not uniformly distributed throughout this part of the kernel is shown by the fact that if about one-quarter of the embryo-free grain is cut off at the embryo end of the seed, that portion near the embryo is more efficient as a source of water-soluble vitamine than is the remainder of the seed, although the latter is by no means devoid of potency. The high vitamine activity of the commercial embryo meal may be caused by a considerable proportion of the softer parts of the endosperm adjacent to the embryo, which in the milling process is removed together with that part of the seed. Our experiments appear to make it certain that if the vitamine is a single substance needed for adequate nutrition, it must be a constituent of the endosperm. The fact that those rats receiving the pure embryo as the sole source of water-soluble vitamine were well maintained for many weeks without growing, whereas those rats receiving the embryo-free grain grew normally, raises the question as to whether the water-soluble vitamine is a single substance or a mixture of two or more.

A previous report has referred to the desirability of securing some reliable information regarding the comparative nutritive values of the total proteins of different cereal grains which play a prominent part in both human and animal feeding. It was hoped to accomplish the comparison of the cereal proteins aside from other complicating factors by removing the greater part of the starch from the rest of the seeds. The experiments with protein products concentrated in this way have not proved so satisfactory as was anticipated. Hence we have developed

a method whereby it became possible to feed the entire seed, and thus compare the untreated protein of the various grains. We are now engaged in such a comparative study of barley, oats, rye, and wheat as sources of protein, feeding each at different protein levels and comparing the efficiency of the growth made on each. These studies also furnish information respecting the economy of protein in nutrition.

In making such comparative tests in the past, it has been difficult to interpret the results accurately, because individual animals eat different quantities of food and consequently grow at different rates. In some experiments we obviated this difficulty by limiting the amount of food given the rats to such a quantity that all the animals grew at approximately the same rate, and ate practically the same amount of food during the same period. The only variables were the kind and percentage of protein employed. This method was exceedingly laborious, and the outcome was not entirely satisfactory.

As a result of some of our work on the value of the proteins found in the different parts of the wheat kernel, we developed a method for assigning a numerical value to each protein, based on the ratio between the amount of protein eaten and the gain in body-weight during a given length of time, starting at approximately the same initial weight. Although this method does not eliminate the individual differences of the animals in their ability to utilize their food economically for maintenance or growth, nevertheless, where pronounced differences in the nutritive value of the various proteins exist, the effect of these may be compared by means of the numerical values thus assigned to the proteins. For example, when wheat flour furnished all the protein of the diet, the rats gained on an average only 0.5 gram of body-weight per gram of protein eaten, whereas when the food contained the *same percentage* of protein consisting of a mixture of two parts of wheat-flour protein and one part of egg protein, the rats gained on an average 2.0 grams of body-weight per gram of protein eaten. Thus it was shown that the excellent growth of the rats on the flour+egg diets, as compared with the little more than maintenance of those animals on the wheat-flour diets, was not due solely to the larger amount of food eaten in the former case, but rather to the *superior quality* of the protein.

Although this method of comparison and evaluation of proteins has its limitations, it is proving useful in our study of the relative value of the cereal proteins. It is early to draw final conclusions, but the results already obtained seem to point to the probability that the wheat proteins are somewhat inferior to those of barley, oats, or rye. While a rat can grow to full maturity on a diet of the entire wheat kernel supplemented with a suitable salt mixture and butter fat, to do so requires more protein than if the ration contained barley, oats, or rye as its sole source of protein.

Recurring inquiries for information regarding the comparative nutritive values of protein foods and requests for some graphic demonstration furnished the occasion for a series of illustrative feeding experiments demonstrating the unique supplementary value of the proteins of meat, milk, or eggs in enhancing the efficiency of some of the cereal proteins for growth. A group of rats of the same age was fed on the selected diets and after ten weeks the animals were photographed. The series of illustrations thus obtained has aroused much interest in the work. Those animals which had received rations the protein of which was furnished by gliadin (from wheat) or zein (from corn)+ a little tryptophane, failed to grow; those which had received the total proteins of corn grew a little only, whereas those whose diets had contained two parts of protein from wheat-flour or corn-gluten feed, supplemented with one part of protein from milk, eggs, or meat, grew normally and were very large, vigorous rats. At the end of four months these animals were sent to the American Museum of Natural History in New York, where they were stuffed and mounted. One set has been returned to us, and the other placed on exhibition there as the nucleus of an educational exhibit to which we expect to make additions from time to time, and which will illustrate in graphic form some of the fundamental principles of nutrition.

The character of the nitrogen in leaves and other kinds of green foods is a question not only of scientific interest, but also of economic importance. Although during the early part of the last century the presence of protein in green leaves attracted the attention of chemists, attempts to study these were soon abandoned after it was found that proteins could be so much more easily obtained from seeds. During more recent years botanists have made observations on the proteins in green leaves by micro-chemical methods, but no serious attempt, so far as we can discover, has been made by any chemist to isolate and study the proteins obtainable from such sources. Since green foods and hays form so large a part of the nutriment of farm animals, we have thought it essential to further progress in our scientific knowledge of feeding animals to learn as much as possible respecting the protein constituents of some particular leaf. We hoped thereby to develop a method which might be applied to other kinds of leaves and thereby ultimately increase our knowledge of the nutritive value of this class of foods.

Since spinach leaves contain nitrogen equivalent to over 30 per cent of protein, estimated in the conventional way by multiplying by 6.25, we have used these for our study. Only a small part of the nitrogen of the fresh leaf is soluble in water, and much of this becomes insoluble when the leaf is dried. The protein in these dried leaves shows exceptional insolubility in the solvents usually employed for extracting

proteins from other sources. Only by boiling with 60 per cent alcohol containing 0.2 per cent of sodium hydroxide have we been able to extract any considerable part of it. We expect to publish the results thus far obtained in the near future, and shall continue work on this subject in the hope that before long we shall learn something of the chemistry, as well as of the nutritive properties, of this peculiar type of protein which will be of value.

Attention has also been given to the hydrolytic action of dilute alkalies at 100° on proteins. This work, which is an extension of our earlier study of the different forms of nitrogen in protein bodies, promises results of interest and will be continued as opportunity presents.

Many of the so-called practical feeding experiments made in the past were done apparently with little appreciation of the complexity of the factors involved; hence the results obtained proved disappointing when attempts were made to apply them in practice. For example, the farmer has been instructed to feed a given proportion of protein (the so-called nutritive ratio) if he is to expect maximum yields in feeding for growth, milk production, eggs, fattening, or simply maintenance. In determining the proper proportion of protein for these different types of feeding, no attention had been paid to the *quality* of the protein, the proportion having been established simply by feeding a few animals on rations customarily in use at the time the experiments were made. Experience on the farm soon showed that this method had serious limitations, and inasmuch as so many kinds of protein concentrates have come into general use, few farmers are to be found who do not also give consideration to the kind of protein these furnish. In other words, the farmer has learned by practical feeding that the kind of protein does make a difference in the amount of product he obtains and that the nutritive ratio alone is not a sufficient guide. His experience is in full accord with what we have learned about the relative nutritive value of the different proteins in our investigations conducted under previous grants, and emphasizes anew the importance of extending this knowledge so that agricultural practice of feeding can be put on a truly scientific basis. Now that methods of feeding have been developed which permit changing one factor at a time, this same method is being used by others to study the nutritive requirements of domestic animals in such a way that results of real value are being obtained.

Our feeding methods, permitting as they do the study of individual constituents of the ration, have also been found useful in studying the effect of poisons and various drugs, and, indeed, have opened up a large field for investigations of various kinds. These methods are already being employed by the Bureau of Chemistry of the Department of Agriculture.

In order to test any given substance for the presence or absence of either the fat-soluble or the water-soluble vitamine, or to make quantitative comparisons of different substances with regard to their value as sources of either of these vitamines, one must be certain the basal ration is as free as possible from whichever one of these food essentials is being tested. Inasmuch as neither of these vitamines has been isolated nor chemical tests for its presence devised, the only method of assuring oneself of the suitability of any given diet as a basal ration is to feed a number of rations containing various ingredients and compare the behavior of the animals on the different diets. The starch, salts, and fats used in the foods have been proved to contain little if any of the water-soluble vitamine, hence the protein is the only constituent which might be contaminated. To test this point, and to determine the most satisfactory method of preparing protein for use in basal rations for studies on the distribution of the water-soluble vitamine, a series of rats was fed on diets essentially alike, except that the protein was derived from widely differing sources and prepared by widely differing methods. When the protein was casein (either very crude or very carefully purified), washed meat residue, lactalbumin, gliadin, ovovitellin, or very carefully purified edestin, the animals began to decline within two or three weeks and with very few exceptions were either dead or moribund in 40 to 60 days. On the other hand, when the protein was either cottonseed globulin or less carefully purified edestin, the animals were maintained without appreciable loss of weight for 100 days, and when the amount of protein in the food was doubled the animals gained slightly in weight, demonstrating that the water-soluble vitamine had not been entirely removed from the preparations of these two proteins. The uniform results obtained with the other isolated proteins indicates that they are nearly, if not wholly, free from the water-soluble vitamine and also that any one of them is suitable to use in a basal ration for experiments concerning the water-soluble vitamine.

A similar series of experiments has been started to test a number of different isolated proteins for the presence of adherent fat-soluble vitamine. These experiments have not progressed sufficiently to justify final conclusions, but the fact that almost without exception the rats on such diets have grown at least some, would indicate that either these diets contain traces of fat-soluble vitamine or else animals can grow for a short time without being furnished more than very slight traces of this vitamine in the diet. It is probable that the lard used did not contribute an appreciable amount of this food substance to the ration, because "lard oil," prepared by extracting lard with absolute alcohol at about 70°, according to the method used in making our very effective "butter oil," did not prevent the decline of rats fed on a diet containing no known source of fat-soluble vitamine.

When all of the ingredients of the food were thoroughly extracted with absolute alcohol, rats were unable to make more than very slight growth. Whether this is due solely to the removal of all traces of fat-soluble vitamine, or whether the alcohol removes some other hitherto unsuspected essential of a perfect dietary, is a problem which we are investigating at present.

The study of the distribution of the fat-soluble and water-soluble vitamines in different vegetable products, alluded to in the report for 1918, has been extended beyond the preliminary stage. The vegetable products thus far studied include alfalfa, clover, timothy, spinach, and cabbage leaves, the bulb of the onion, the roots of carrots and turnips, the leaves, stems, and root of the beet, the tuber of the potato, and the fruit of the tomato. All of these have been demonstrated to contain more or less of the water-soluble vitamine, and all but the onion, turnip, and beet roots have been found to furnish at least some of the fat-soluble vitamine.

In order that the various foods may be so used as to insure an adequate supply of the vitamines, it is important to know not only how widely these essential food factors are distributed, but also how the different natural foods compare with each other as sources of these accessories. Consequently a carefully controlled series of quantitative experiments designed to show the relative abundance of these vitamines in some of these various vegetable products is now in progress; but these investigations have not yet been continued long enough to permit drawing final conclusions.

In the case of the potato, the water-soluble vitamine is apparently distributed throughout the entire tuber, although it is more concentrated near the surface than in the center; for potatoes which were pared before cooking and then dried were found to be considerably less rich in this food factor than were the whole potatoes, which were cooked and dried without removing the skin.

It has been stated that the fat-soluble vitamine can not be extracted from plant tissues with ether. We have found, however, that the ether extract of spinach leaves or of immature alfalfa or clover plants or of young grass is comparatively rich in this vitamine. As little as 30 mg. of "spinach oil" per day, fed to a rat which had declined in weight owing to a lack of the fat-soluble vitamine in the ration, was sufficient to restore the animal to a good nutritive condition, as well as to cure the eye disease which frequently occurs as the result of the lack of this food constituent.

One feature, which hitherto has received no adequate consideration, is the possible dependence of the vitamine content upon the maturity of the plant product. To test this point samples of mature alfalfa, clover, and timothy hay were obtained from the same fields from which the immature specimens were obtained earlier in the season. In every

case it was found that weight for weight the mature hay was much less efficient as a source of water-soluble vitamine than was the immature plant. If it should be proved that the vitamine content of milk is influenced by the vitamine content of the ration of the dairy cow, it is quite possible that proportion of vitamine in milk could be increased by feeding hay made from young, immature plants instead of that made from the more mature ones. Inasmuch as milk has been found to be somewhat less rich in the water-soluble vitamine than was supposed at one time, it would be a great advantage if some means could be found for increasing its content in this food accessory, especially for the sake of children and invalids, who quite possibly not infrequently suffer from an insufficient supply of this unidentified essential.

Our experiments, as well as those of other investigators, have shown that animals require a supply of the water-soluble vitamine throughout their entire lifetime. Whether or not the need for the fat-soluble vitamine is also manifested during the complete life cycle or only during certain periods is still an unsolved question. To investigate this, a number of fully mature animals were fed rations supposedly free from this food accessory and on which young rats inevitably would cease to grow and would decline in weight after about three months. Some of these adult animals have received such diets exclusively for nearly a year without manifesting any of the obvious symptoms characteristic of animals fed on a diet deficient in this vitamine. Whether or not these animals have suffered disturbances in their metabolic processes has not been determined. In this connection we recall the incidence of urinary calculi among rats fed on diets deficient in fat-soluble vitamine already referred to in an earlier report. Another series of animals which had received limited quantities of the fat-soluble vitamine during the early part of their growing period was deprived of this food accessory just before they had reached full maturity. These were well maintained, and some even grew considerably during the next six months; but eventually they declined suddenly in weight, and were then brought back to a condition of normal nutrition by the administration of butter fat, or some other source of the fat-soluble vitamine, without any other change in the food. Apparently adults do not need so abundant a supply of fat-soluble vitamine as do growing animals, but our experiments have not yet justified final conclusions in respect to this important problem. If the results of our still incomplete experiments can be applied to human nutrition, it would seem that adults need less fat-soluble vitamine than do growing children in order to avert nutritive disaster, but, in view of our present limited knowledge of this subject, the fat-soluble vitamine should not be eliminated entirely from the dietary of adults.

Inasmuch as we have used yeast extensively as a source of water-soluble vitamine in our nutrition experiments, and particularly in

test diets in which the presence or absence of the fat-soluble vitamine was under investigation, it became essential to ascertain conclusively whether the yeast was also perchance contributing some of the fat-soluble component. Having demonstrated that dried brewery yeast is an adequate source for the protein and water-soluble vitamine needed during growth, we fed young rats upon a diet consisting of dried yeast, starch, a salt mixture, and lard. They made a little growth and began to decline in weight after 51 to 72 days; but growth was promptly renewed when butter fat was added to the ration. Inasmuch as the diet contained 42.5 per cent of yeast, it seems to be conclusively shown that the few centigrams of yeast commonly added as a source of water-soluble vitamine to our mixtures of isolated food substances can not be the carrier of significant amounts of the fat-soluble vitamine. This is in accord with the recently published conclusions of Drummond.

In preparing food materials as free as possible from all traces of fat-soluble vitamine by extraction with boiling absolute alcohol, the yeast was subjected to a similar treatment. Special tests which have been conducted with this extracted product in combination with a vitamine-free diet have shown that the water-soluble vitamine is not lost by the mode of treatment indicated.

The question has been raised as to the possible destructive influence of the high temperatures employed in the canning industry. To test this point, samples of washed meat residue and yeast were heated at about 20 pounds pressure for an hour. The rats fed on rations containing the pressure-cooked meat residue grew just as well as those which received the ordinary preparation of meat residue, showing that the long cooking apparently had no unfavorable influence on the value of the protein. The pressure-cooked yeast, although it was by no means inactive, proved to be somewhat inferior to the uncooked yeast as a source of water-soluble vitamine, showing that heating for an hour at high temperatures tends to destroy the water-soluble vitamine. In practice, however, few, if any, of the canned products are subjected to such a high temperature for so long a time as were these, so that it is probable that under ordinary circumstances the *water-soluble vitamine* in canned goods is not seriously damaged. This statement does not apply to the anti-scorbutic potency of foods.

That the water-soluble vitamine is not destroyed by long storage is shown by the fact that yeast, protein-free milk, and various vegetable products which have been kept for a year or longer have shown no appreciable diminution in their vitamine potency.

One well-grounded objection to the experiments made in the past to determine the nutritive value of the individual proteins in the pure state has been founded on the fact that in furnishing the vitamine necessary to the animal's existence not inappreciable quantities of

nitrogen of unknown character are also introduced into the diet. There is therefore a question whether or not this nitrogen does not in fact supplement deficiencies in the protein. If, however, a preparation of vitamine could be obtained which was so potent that very small quantities were enough to meet the animal's requirement the amount of nitrogen and other substances thus introduced might be so small as to render objections of the above sort of little force.

We have accordingly devoted much time to attempts to prepare such a product from yeast and are now in possession of a relatively large amount of material which, according to the trials thus far made with it, appears nearly if not quite as efficient in supplying the water-soluble vitamine as was the yeast itself from which it was obtained. Thus daily doses of 16 milligrams of this product have proved about as effective in restoring rats which have declined on a diet free from water-soluble vitamine as have doses of 200 milligrams of the original dried yeast. Such a quantity of dried yeast appears to be in general about the minimum which can be depended on promptly to bring declining rats back to normal.

Although it is improbable that *all* of the water-soluble vitamine of the yeast is concentrated in the material now on hand, this product is far more potent than any we have heretofore had at our command. This fraction contains only 7.5 per cent of nitrogen, hence only 1.2 milligrams of nitrogen are added to the daily diets of 5 to 10 grams of our foods rich in fat. Such a quantity can scarcely be expected to affect the nutritive value of the protein in such foods. Thus, if the food intake of a very young rat is 5 grams per day and this contains 10 per cent of protein, its nitrogen content is 80 milligrams. The 1.2 milligrams of nitrogen added with the vitamine is, therefore, less than 1.5 per cent of the total nitrogen of the food. With increasing food intake the added nitrogen forms a correspondingly smaller proportion. It is probable that we shall soon learn to concentrate the vitamine still further and thereby correspondingly reduce the uncertainties which have heretofore pertained to some of our experiments.

We also hope to chemically define the water-soluble vitamine still more narrowly by excluding various groups of substances whose absence from the effective fraction can be demonstrated. Some groups have already been excluded, and it is confidently expected that others may soon be added to this list. In this way it ought to be possible to simplify the problem of ultimately establishing the chemical identity of this mysterious food factor. Some light may also be gained on the question of whether what is now termed the water-soluble vitamine is a single substance or a mixture of two or more, as our experiments with wheat embryo suggest. As we have only recently been able to prepare a sufficient supply of this yeast fraction, its chemical examination has just been begun.

PALEONTOLOGY.

Case, E. C., University of Michigan, Ann Arbor, Michigan. *Study of the vertebrate fauna and paleogeography of North America in the Permian period, with especial reference to world relations.* (For previous reports see Year Books Nos. 2, 4, 8–17.)

Since submitting the last report, Dr. Case has devoted his time to the preparation of the manuscript of Publication No. 283, on the "Environment of vertebrate life in the late Paleozoic of North America." Since the completion of this work he has begun the compilation of material which, it is hoped, will show the environment in which the vertebrate animals of other parts of the world developed during the same period of time as is covered by this publication. In the summer of 1919 Dr. Case spent several weeks studying the Permo-Triassic boundary-line in the southwestern part of the United States.

Hay, Oliver P., U. S. National Museum, Washington, D. C. *Associate in Paleontology.* (For previous reports see Year Books Nos. 11–17.)

The greater part of the past year has been devoted to a study of the Pleistocene vertebrates and to the Pleistocene geology of Quebec, Ontario, the New England States, West Virginia, Ohio, Kentucky, and Tennessee. The regions lying on each side of the St. Lawrence River and lakes Ontario and Erie are covered by the deposits laid down by the last ice sheet, the Wisconsin. In the loose deposits overlying the Wisconsin drift are buried remains of animals which survived the last period of cold or which entered the country after this geologic stage had ended. In comparison with that of the early Pleistocene an impoverished fauna is indicated. For New York, the publications of Dr. H. L. Fairchild were of great service to the present writer. As the Wisconsin ice sheet retired, the water of the Great Lakes stood at successively lower levels. In deposits made at nearly the present level of these lakes in the region now reported on, as well as that along lakes Huron and Michigan, have been found teeth and bones of mastodons, two species of elephants, and extinct peccaries, proofs that these animals existed there until only a few thousand years ago.

In the limestones of the Alleghany region, from central Pennsylvania to northern Alabama, are found numerous caves and fissures. These have furnished and are still furnishing abundant remains of vertebrated animals, mostly mammals. These belong principally to extinct species, and appear to have existed during the middle or early Pleistocene. Every effort ought to be made to preserve all such remains, often met with accidentally.

Some weeks have been devoted to the study and description of the species of several small but valuable collections. Some of these, as two from caves in Tennessee, one made at Alton, Illinois, and another made at Afton, Oklahoma, have lain undescribed for many years. They are furnishing much new and interesting information. Another

important collection was made a few years ago by Dr. W. K. Moorehead, of Phillips Academy, from a fissure near Cavetown, Maryland; still another was made for the writer about 3 years ago from a cave near San Antonio, Texas.

As a sort of by-product of his work on the Pleistocene, and compiled mostly outside of office hours, the writer is preparing a continuation of his Bibliography and Catalogue of Fossil Vertebrata of North America. This is intended to bring the records up to date.

Wieland, G. R., Yale University, New Haven, Connecticut. *Associate in Paleontology.* (For previous reports see Year Books Nos. 2–4, 6–9, 11–17.)

Cycadeoid and related studies earlier outlined have been continued, except the investigation of Mesozoic gymnosperm stem structure. Here material has still further increased and a broader field is outlined.

In volume II (Publication No. 34) on the petrified cycads, a subsidiary attention was given to the cycadeous vegetation of the Jurassic and later time. Following this same plan, in volume III, in course of preparation, a considerably more searching restudy of the Triassic cycadophytes is being attempted. So far as the petrified series is concerned, certain studies of finely conserved trunks, in interest recalling the *Cycadeoidea dartoni*, are being added. In particular, through the courtesy of the custodians of the State University of Iowa collection, the remarkable original type of Macbride, *Cycadeoidea dacotensis*, is now being sectioned at the U. S. National Museum.

Some field work has also been done, and the Western localities have been revisited for the purpose of locating the best point for quarrying for petrified cycads. Two such quarries are now fairly located. Also, in connection with the general subject of petrified forests, incidental attention has been given to the remarkable Carboniferous forests of this kind near Athens, Ohio, first reported by Lesquereux in 1859.

The subject of the mode of dicotyl leaf modification from the more gymnospermous and fern-like ancestral types of mid to lower Mesozoic time was noted last year, and some headway has been made. It is now clearer that there is an easy transition from the more primitive blades (the *Stangeria* type) to bipinnate (specialized) types of cycad fronds. Furthermore, that pinnate blades like those of the oleander and magnolia find near antecedents in pinnate cycadeoid leaves has been pointed out. This holds from both the morphologic and stratigraphic viewpoint. But the general features of Lower Cretaceous foliage show such a close transition from pinnate to palmate dicotyls that both may be regarded as equally primitive, although the latter appear the more abruptly. Hence the change from Jurassic to Cretaceous leaf-types could take place far more rapidly as a parallel movement than as more local movements, or evolution of the kind hitherto expressed by the so-called "paleontologic tree."

Another result expressible in general terms, but directly important, bears on the use of fossil plants as climatic indices. Any Mesozoic cycadeoids, or any other gymnosperms leading into or toward the early dicotyls, must have had much the same capacity for zonal distribution as present-day dicotyls and gymnosperms. There is therefore need for caution in viewing Cycadophyte floras as proof of uniform tropic conditions. The view has long been current that from the late Triassic throughout the Jurassic and Cretaceous, "there were no distinct polar, temperate, or equatorial zones," and that [essentially] the same plants are found from within a few degrees of the poles all the way to the equator. Here, too, old evidence must be reviewed, and long-held opinions must evidently be revised.

PHYSICS.

Barus, Carl, Brown University, Providence, Rhode Island. *Continuation of investigations in interferometry.* (For previous reports see Year Books Nos. 4, 5, 7–17.)

The peculiar behavior previously observed in treating the elastic deformations of small bodies on the interferometer induced the author to construct the contact lever, using achromatic fringes described in the beginning of the report. The instrument at once functioned admirably when employed either as a surface tester or as a spherometer. This contact lever was then modified for the interpretation of the elastic discrepancies specified, and the conditions shown under which both the new and the old methods lead to trustworthy results.

In a different application of the contact lever the small elongations with subsequent contractions experienced by iron in magnetic fields are treated. They are peculiarly interesting, because these phenomena are at their maximum variation after the metal has become practically saturated. Furthermore, an instrument which lends itself with equal facility to the measurement of thermal expansion and of moduli is in a measure self-contained for the solution of many thermodynamic problems.

Electrodynamometry of very weak (telephonic) currents.—No available effect is obtainable, unless the vibrator of the measuring instrument is sharply in resonance with the alternating current; then the response is astonishingly large and definite. When the measurement is made by the vibration telescope, the vibrator of the telephonic system carrying the objective, the sensitiveness obtainable is not beyond a few microamperes per ocular scale-part of reasonable value (0.01 cm.). Within these limits, however, it may be made serviceable, for instance, in determining the number of turns in each of a variety of secondary coils, successively slid over the same long solenoidal

primary. The sensitiveness may be increased upwards 100 fold, however, so that 10^{-8} ampere per fringe is still measurable, by placing a similar instrument on the displacement interferometer adjusted for achromatic fringes. The reading in such a case must be made with a vibration telescope, synchronized with the alternating current in the primary and with the objective vibrating normally to the displacement of fringes. The measurement is thus somewhat awkward and consists in determining the range of the fringe ellipses parallel to the direction of vibration of fringes. On the other hand, both the amplitude and the phase of the induced current, whether modified by resistance, inductance, or capacity, is given by the form of vibration ellipses obtained.

A slight but essential modification of a form of interferometer used by Michelson and Morley makes the apparatus virtually self-adjusting, yet satisfying many requirements in displacement interferometry. This is a great convenience when many separate adaptations of apparatus to the interferometer have to be successively made. It is even possible to put a part of one of the mirrors on a micrometer-screw for direct measurement. The endeavor to use this device for finding the refraction of solid media did not, however, lead to results of practical value. On the other hand, a possible design of this kind for measuring the Fresnel coefficient is being tested with a promising outcome.

An interesting class of interferences is obtained by the superposition of fringes due to dispersion on identical fringes due to the inclination of rays. It is possible in this way to obtain sharp spectrum fringes in the very luminous spectrum of an indefinitely wide slit and to determine the angular orientation of the spectro-telescope on its axis; for the fringes, if small, suddenly jump out of an unbroken spectrum band when a definite angle is reached. A number of results incidental to the preceding work are shown. Evidences of continuous micrometric convection currents within liquids, obtained from the shadows of motes in a highly dispersed spectrum; the satellites of the achromatic fringes already referred to in a preceding report; peculiarly brilliant phenomena obtainable in connection with Herschel's fringes; and other subjects, are here treated.

The gravitational experiments begun in the last report have been continued. The former, in which the deviations of the horizontal pendulum are read off by the displacement of achromatic fringes, is very definite in its evidence of the effect of temperature distributions within the pier. The author is inclining to the conviction that measurements of the gravitational attraction of two bodies made daily, for a period of years, might not be unproductive of results. To do this effectively, however, a full analysis of the thermal and other radiation discrepancies must first be available, and work with this end in view is being actively pursued.

Howe, Henry M., Bedford Hills, New York. *Research Associate in Metallurgy.* (For previous reports see Year Books Nos. 6–17.)

I began at my own laboratory a systematic search for the kind of steel most suitable for helmets and body armor, at the request of the Ordnance Department, of which I became a civilian expert. For this I devised apparatus for accurate ballistic testing, with normal impact, of the spherical surfaces of which the front and rear of helmets consist. Later this work was taken over and finished by Mr. W. J. Wrighton. The Ordnance Department has authorized the publication of our results.

I have studied the nature and causes of the peculiar white coarse-grained spots called "snowflakes" which occur in the otherwise fine-grained fractures of the test pieces of certain alloy steels. I find that they represent internal fissures made at a time when the structure of the metal itself was coarse-grained like these spots. The fact that, even when they represent as much as one-fourth of the sectional area of the test-piece, they cause no appreciable lowering of the elastic limit, I explain as meaning that the stretch which occurs on passing the lowered elastic limit of the cross-section where thus reduced by the fissure, being confined strictly to this cross-section, is too minute to be detected by any extensometer. Instead, the elastic limit actually observed is that of the unfissured remainder of the test-piece when enough stretch has occurred at innumerable points along its length to add up to a measurable quantity. This general line of thought is due to Professor H. F. Moore.

With Mr. R. C. Groesbeck I have studied the four following subjects, chiefly at the U. S. Bureau of Standards:

(1) The influence of the conditions of casting on the position of the internal contraction cavity or pipe in solidifying masses. The experiments were made with ingots of paraffin.

(2) The influence of the severity of reduction in the individual passes in rolling metals on the residual internal stresses. We rolled steel strips in pairs, one strip superposed on the other, and measured the degree by which these strips became bent, for given total reductions, when this reduction was brought about by a few severe reductions, by many light ones, and by an intermediate number of reductions of moderate severity. The deflection increases with the severity of the reduction per pass. This is referred to the greater skin friction between the rolls and the piece rolled, which lessens the backward flow of the surface metal, thus causing a correspondingly greater proportion of the flow to occur in the deeper-seated layers.

(3) The influence of phosphorus on the microstructure and hardness of carbon steel after various thermal treatments. For this we used the important series of steels varying greatly in their phosphorus content, but otherwise alike, prepared by Mr. J. S. Unger for another purpose.

(4) The influence of thermal treatment on the microstructure of pure carbon steels of various carbon contents.

Nichols, E. L., Cornell University, Ithaca, New York. *Systematic studies of the properties of matter through a wide range of temperatures.* (For previous reports see Year Books Nos. 4–17.)

Researches under this grant have been greatly retarded during 1918–19 by conditions resulting from the war. A monograph, describing investigations on the fluorescence, phosphorescence, and absorption of the uranyl salts, has been completed, however. It deals with the work of several observers over a period of eight years and is a fairly exhaustive survey of one of the most important fields in the domain of luminescence.

In the course of these researches, the spectra of numerous uranyl compounds were mapped and discussed. Many of these salts, including the various chlorides, nitrates, acetates, sulphates, and phosphates, were especially prepared for this purpose by Dr. Wilber.

A comparative study of the results obtained has led to the following:

General Conclusions Concerning the Luminescence of the Uranyl Salts.

The entire spectrum of any given uranyl compound is an *homogeneous complex.*

The criteria of homogeneity are: (*a*) *Independence of the mode of excitation.*—The uranyl spectra meet this test completely. Any wavelength of light, capable of producing fluorescence, brings out all the bands and, so far as we have been able to determine, with the same relative intensities. Numerous attempts at selective excitation (*i. e.*, to produce a single group or series or even to enhance portions of the spectrum, by the use of monochromatic illumination), have given negative results. Kathode-luminescence and X-ray excitation, moreover, give the same spectrum as photo-excitation. This is true of single bands in the spectra of other fluorescent substances, *e. g.*, the green band of Sidot blende; but rarely if ever, of the entire spectrum, save in the case of the uranyl salts. (*b*) *Identity of the fluorescence spectrum and the phosphorescence spectrum*, or, what is nearly the same, of the phosphorescence spectrum during the earlier and later stages of decay. Conformity with this criterion was established for several uranyl salts by Misses Wick and McDowell in their studies of kathodo-phosphorescence. It is not a test easily applicable to all such compounds, because the phosphorescence under photo-excitation is of the vanishing type. Comparatively few uranyl salts, on the other hand, are sufficiently stable in vacuo, especially under exposure to kathode rays, to permit of a detailed examination by that method.

Heterogeneity in a fluorescence spectrum of the usual broad-banded type, such as is universal with the phosphorescent sulphides for example, is not readily detected by spectroscopic observation on account of the overlapping of the bands, but it often manifests itself in the most striking manner by changes of color during the decay of phosphores-

cence. This is due to differences in the rate of decay of the components of a mixed luminescence, and affords another and simple criterion, *i. e.*, absence of color change during the phosphorescence period. This can be tested, even for substances of exceedingly brief phosphorescence, such as the uranyl salts, by the use of the disk phosphoroscope.

The absence of color change of the fluorescent light, when luminescence is produced at low temperatures. Such changes are marked in the case of heterogeneous luminescence and afford a conclusive indication.

By such criteria we are led to the conviction that the uranyl spectrum is a unit, appearing in its entirety, however produced, and disappearing as a whole when excitation ceases. This is a unique characteristic, so far as our present knowledge goes. It is certainly not true of the fluorescent dyestuffs, of the phosphorescent sulphides, of the rare earths, or of the luminescence of vapors.

Another fact, even more impressive and significant, which was fully recognized only after the completion of our detailed studies of the spectra of numerous salts under varying conditions, when we were in position to view them as a whole, and to make comparisons based upon adequate data, is this:

There is but one spectrum, *the uranyl spectrum*, common to all uranyl salts. Of a complexity which has not as yet been completely resolved and analyzed, its essential structure is always the same. This statement is based upon the following characteristics typical of all the spectra thus far examined.

(1) All uranyl spectra have the same number of equidistant fluorescence bands.

(2) This set of bands occupies in all cases the same region of the spectrum, lying, roughly, between 0.6500μ and 0.4800μ.

(3) The distribution of intensities is always the same, rising from the merest visibility in the red to a definite crest and diminishing more rapidly towards the violet.

(4) Fluorescence and absorption always overlap in the so-called reversing region.

(5) The frequency interval for absorption series is always smaller than for fluorescence series, and the ratio is nearly the same for all compounds.

(6) Fluorescence and absorption bands are always complex, although not generally visibly so at $+20°$. Resolution of the bands into groups always occurs on cooling in the case of crystalline compounds. Liquid or non-crystalline preparations are not resolved by cooling.

Accompanying these universal attributes are numerous minor and perfectly definite variations, which tend to obscure but never actually conflict with the general uniformity of type. These enable one to identify, with certainty, the spectra of the various compounds, especially when excitation occurs at low temperatures.

These variations consist chiefly in the number, spacing, precise location, relative brightness, and sharpness of the narrow bands in the groups into which the bands are resolved on cooling; in slight differences in frequency intervals of the fluorescence series and absorption series; in slight shifts in location of the groups as a whole, and of shifts and minor rearrangements which appear to be dependent in some way upon molecular weight, water of crystallization, and particularly upon crystal form.

Minor Investigations Completed, in Progress, or in Prospect.

The work on the luminescence of the rare earths, of which a brief preliminary account has already appeared,[1] is being continued. Spectra of the kathodo-luminescence and absorption of various preparations of the oxides of neodymium, praseodymium, cerium, and erbium are in process of observation and mapping.

Drs. Wick and Wilber have in hand a study of the phosphorescence of these compounds, and Dr. Howes is preparing for the investigation of their luminescence at high temperatures.

Miss Wick is also planning to investigate the photo-luminescence, kathodo-luminescence, and the remarkable tribo-luminescence of the double silicate known as hexagonite.

The results of the study of the selective emission from erbium oxide, made by the late Dr. Mallory, have been published in the Physical Review.[2]

Papers have also appeared on the fluorescence and absorption of the uranyl acetates[3] and sulphates.[4]

---

[1] Physical Review (2),

[2] Mallory (with a note by E. L. Nichols): Physical Review (2), vol. 14, p. 54 (1919).

[3] Nichols, Howes, and Wick: Physical Review (2), vol. 14, p. 201 (1919).

[4] Nichols and Howes: Physical Review (2), vol. 14, p. 293 (1919).

INDEX.

Date of Issue	Date of Issue	Date of Issue
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....